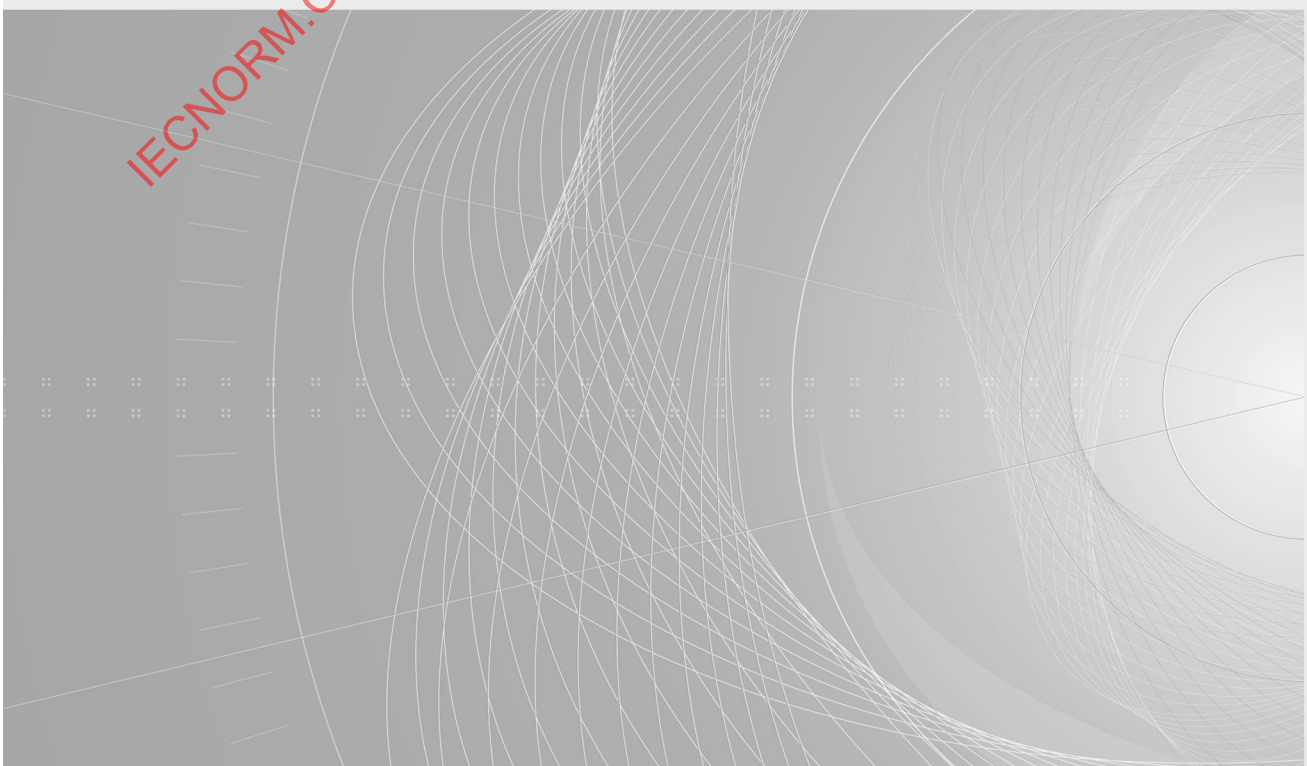
IEC 60086-4

Edition 6.0 2025-01
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

Primary batteries –
Part 4: Safety of lithium batteries



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Primary batteries –
Part 4: Safety of lithium batteries

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This commented version (CMV) of the official standard IEC 60086-4:2025 edition 6.0 allows the user to identify the changes made to the previous IEC 60086-4:2019 edition 5.0. Furthermore, comments from IEC TC 35 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60086-4 has been prepared by technical committee 35: Primary cells and batteries. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Added definitions for leakage and venting, in addition to the test criteria;
b) Revised overdischarge test;
c) Revised marking requirements;
d) Revised criteria for the child resistant packaging test;
e) Changed the purpose of Annex F from "informative" to "normative";
f) Added a new Annex G with additional measures against misuse of batteries not intended for consumer replacement;
g) Integrated the contents of Interpretation Sheet 1 (IEC 60086-4:2019/ISH1:2020);
h) In Clause 3, terms were reordered according their functions: basic terms, electrochemical systems, battery shapes, battery sizes, electrical characteristics, specifications, safety aspects, failure modes;
i) In 6.4.4, the exemption for the shock acceleration for lithium primary batteries was reduced from 12 kg to 4,482 kg in order to reflect the fact that this is the threshold in IEC 62281, Test T-4, where the peak acceleration decreases below 150 g_n.

The text of this International Standard is based on the following documents:

Draft	Report on voting
35/1571/FDIS	35/1579/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

NOTE 1 The following print types are used:

– instructions/warnings for consumers: *in italic type*.

A list of all parts in the IEC 60086 series, under the general title *Primary batteries*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

NOTE 2 The attention of National Committees is drawn to the fact that equipment manufacturers and testing organizations may need a transitional period following publication of a new, amended or revised IEC document in which to make products in accordance with the new requirements and to equip themselves for conducting new or revised tests. It is the recommendation of the committee that the content of this document be adopted for implementation nationally not earlier than 2 years from the date of publication. The transitional period applies specifically to changes in Table 10. In the meantime, the previous edition can still be ordered by contacting your local IEC member National Committee or the IEC Secretariat.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This document specifies tests and requirements for lithium batteries and has been prepared in accordance with ISO/IEC guidelines, taking into account all relevant national and international standards which apply.

Lithium batteries are different from conventional primary batteries using aqueous electrolyte in that they contain flammable materials.

Consequently, it is important to carefully consider safety during design, production, distribution, use, and disposal of lithium batteries. Based on such special characteristics, lithium batteries for consumer applications were initially small in size and had low power output. There were also lithium batteries with high power output which were used for special industrial and military applications and were characterized as being "technician replaceable". The first edition of this document was drafted to accommodate this situation.

However, from around the end of the 1980s, lithium batteries with high power output started to be widely used in the consumer replacement market, mainly as a power source in camera applications. Since the demand for such lithium batteries with high power output significantly increased, various manufacturers started to produce these types of lithium batteries. As a consequence of this situation, the safety aspects for lithium batteries with high power output were included in the second edition of this document.

Primary lithium batteries both for consumer and industrial applications are well-established safe and reliable products in the market, which is at least partly due to the existence of safety standards such as this document and, for transport, IEC 62281. The fourth edition of this document reflected minor changes which became necessary in order to keep it harmonized with IEC 62281 and to continuously improve the user information about safety related matters.

Guidelines addressing safety issues during the design of lithium batteries are provided in Annex A. Annex B provides guidelines addressing safety issues during the design of equipment where lithium batteries are installed. Both Annex A and Annex B reflect experience with lithium batteries used in camera applications and are based on [22][1].

The ingestion hazard of coin cell batteries has become an issue and was addressed in the fifth and sixth editions of this document by several independent measures such as the development of a new safety sign "KEEP OUT OF REACH OF CHILDREN" as well as the introduction of child resistant packaging.

A new Annex C addresses measures against misuse of cells and batteries not intended for consumer replacement.

Safety is freedom from unacceptable risk. There can be no absolute safety: some risk will remain. Therefore a product, process or service can only be relatively safe. Safety is achieved by reducing risk to a tolerable level determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service, and factors such as benefit to the user, suitability for purpose, cost effectiveness, and conventions of the society concerned.

As safety will pose different problems, it is impossible to provide a set of precise provisions and recommendations that will apply in every case. However, this document, when followed on a judicious "use when applicable" basis, will provide reasonably consistent standards for safety.

[1] Numbers in square brackets refer to the Bibliography.

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

1 Scope

This part of IEC 60086 specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.

NOTE Primary lithium batteries that are standardized in IEC 60086-2 are expected to meet all applicable requirements herein. It is understood that consideration of this part of IEC 60086 might also be given to measuring and/or ensuring the safety of non-standardized primary lithium batteries. In either case, no claim or warranty is made that compliance or non-compliance with this part of IEC 60086 will fulfil or not fulfil any of the user's particular purposes or needs.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086-1:2021, *Primary batteries – Part 1: General*

IEC 60086-2, *Primary batteries – Part 2: Physical and electrical specifications*

IEC 62281, *Safety of primary and secondary lithium cells and batteries during transport*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

NOTE Certain definitions taken from IEC 60050-482, IEC 60086-1, and ISO/IEC Guide 51 are repeated below for convenience.

3.1
cell
basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

[SOURCE: IEC 60050-482:2004, 482-01-01]

3.2
battery
one or more cells electrically connected and fitted in a case, with terminals, markings and protective devices etc., as necessary for use

[SOURCE: IEC 60050-482:2004, 482-01-04, modified – "fitted with devices necessary for use, for example case" replaced by "electrically connected and fitted in a case", addition of "etc., as necessary for use".]

3.3
component cell
cell contained in a battery

3.4
lithium cell
cell containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

[SOURCE: IEC 60050-482:2004 482-01-06, modified – removal of Note.]

3.5
coin cell
coin battery
lithium button cell
lithium button battery
small round cell or battery where the overall height is less than the diameter, containing non-aqueous electrolyte.

Note 1 to entry: The nominal voltage of lithium batteries is typically greater than 2 V. See also the definition of "button cell" in IEC 60086-5

Note 2 to entry: See 7.3 for proposed use of the alternative terms.

Note 3 to entry: The terms "lithium button cell" and "lithium button battery" were provided as alternative terms for "coin cell" and "coin battery" in order to prevent the use of the terms "button cell" and "button battery" which would be confusing as they have a different meaning, see part 1 of this standard.

Consequently, the terms "coin cell" and "coin battery" should be omitted in those languages where they have no meaningful literal equivalent.

[SOURCE: IEC 60050-482:2004 482-02-40, modified – terms modified, ~~Note "In practice terms, the term coin is used exclusively for non-aqueous lithium cells." replaced with a different note)~~ Note replaced.]

3.6
cylindrical cell
cylindrical battery
round cell or battery in which the overall height is equal to or greater than the diameter

[SOURCE: IEC 60050-482:2004, 482-02-39, modified – "cell with a cylindrical shape" replaced by "round cell or battery".]

3.7
prismatic cell
prismatic battery
cell or battery having the shape of a parallelepiped whose faces are rectangular

[SOURCE: IEC 60050-482:2004, 482-02-38]

3.8
large cell
cell with a gross mass of more than 500 g

3.9
large battery
battery with a gross mass of more than 12 kg

3.10
nominal voltage
suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

[SOURCE: IEC 60050-482:2004, 482-03-31]

3.11
open circuit voltage
OCV, U_{OC}, off-load voltage
voltage across the terminals of a cell or battery when no external current is flowing

[SOURCE: IEC 60050-482:2004, 482-03-32, modified – alternative terms "OCV, U_{OC}, off-load voltage" added, "across the terminals" added, "when the discharge current is zero" replaced with "when no external current is flowing".]

3.12
rated capacity
capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – "cell or" added.]

3.13
depth of discharge
DOD
percentage of rated capacity discharged from a cell or battery

3.14
undischarged
state of a primary cell or battery at 0 % depth of discharge

3.15
fully discharged
state of a cell or battery at 100 % depth of discharge

3.16
harm
injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.17
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.18
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified – removal of Note.]

3.19
safety
freedom from risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.20
intended use
use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

[SOURCE: ISO/IEC Guide 51:2014, 3.6]

3.21
reasonably foreseeable misuse
use of a product, process or system in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – removal of Notes.]

3.22
protective devices
devices such as fuses, diodes or other electric or electronic current limiters designed to interrupt the current flow, block the current flow in one direction or limit the current flow in an electrical circuit

3.23
leakage
unplanned escape of electrolyte, gas or other material from a cell or battery 1

Note 1 to entry: Leakage in this sense should not be confused with the test evaluation criteria for leakage specified in Clause 6.

3.24
venting
release of excessive internal pressure from a cell or battery in a manner intended by design 2

Note 1 to entry: Venting in this sense should not be confused with the test evaluation criteria for venting specified in Clause 6.

4 Requirements for safety

4.1 Design

Lithium batteries are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, coin and prismatic configurations. It is necessary to consider all relevant safety aspects at the battery design stage, recognizing the fact that they can differ considerably, depending on the specific lithium system, power capability and battery configuration.

The following design concepts for safety are common to all lithium batteries:

a) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.

a) Temperature increases in the battery shall be controlled by a design which limits current flow.

b) Lithium cells and batteries shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, intended use and reasonably foreseeable misuse.

If, in particular cases, this design concept cannot be implemented, the organisational requirements described in Annex G shall apply.

See Annex A for guidelines for the achievement of safety of lithium batteries.

4.2 Quality plan

The manufacturer shall prepare and implement a quality plan defining the procedures for the inspection of materials, components, cells and batteries during the course of manufacture, to be applied to the total process of producing a specific type of battery. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product safety.

5 Type testing and sampling

5.1 Validity of testing

Lithium cells or batteries shall be subjected to the tests, as required in this document. Testing remains valid until a design change or requirement revision has been made. Retesting is required when:

a) a battery specification changes by more than 0,1 g or 20 % mass, whichever is greater, for the cathode, anode or electrolyte;

b) a battery specification change would lead to a failure of any of the tests;

c) there is an addition of new tests or requirements; or

d) there is a requirement change that would lead to a failure of any of the tests.

5.2 Test samples

Samples should be drawn from production lots in accordance with accepted statistical methods. The number of test samples is given in Table 1. The same test cells and batteries are used for tests A to E in sequence. New test cells and batteries are required for each of tests F to M.

Table 1 – Number of test samples

Tests	Discharge state		Cells ~~and~~ or single cell batteries[a]	Multi-cell batteries
Tests A to E	Undischarged		10	4
	Fully discharged		10	4
Test F or G	Undischarged		5	5 component cells
	Fully discharged		5	5 component cells
Test H	Fully discharged		10	10 component cells
Tests I to K	Undischarged		5	5
Test L	Undischarged		20[b] ~~(see Note 1)~~	n/a
~~Test M~~	~~50 % predischarged~~		~~20 (see Note 2)~~	~~n/a~~
	~~75 % predischarged~~		~~20 (see Note 3)~~	~~n/a~~
Test M	50 % predischarged	CR	10[c]	n/a
	Fully discharged	CR	10[d]	n/a
	50 % predischarged	FR	20[e]	n/a
	Fully discharged	FR	20[f]	n/a

Key

n/a: not applicable

[a] Single cell batteries containing one tested component cell do not require re-testing unless the change could result in a failure of any of the tests.

~~NOTE 1 Four batteries connected in series with one of the four batteries reversed (5 sets).~~

~~NOTE 2 Four batteries connected in series, one of which is 50 % predischarged (5 sets).~~

~~NOTE 3 Four batteries connected in series, one of which is 75 % predischarged (5 sets).~~

[b] Four batteries connected in series with one of the four batteries reversed (5 sets).

[c] Two CR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.

[d] Two CR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.

[e] Four FR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.

[f] Four FR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.

6 Testing and requirements

6.1 General

6.1.1 Test application matrix

Applicability of test methods to test cells and batteries is shown in Table 2.

Table 2 – Test application matrix

Form	Applicable tests												
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	x	x	x	x	x	x [a]	x [a]	x	x	x	x	x [b]	x [c]
m	x	x	x	x	x	x [a, d]	x [a, d]	x [d]	x	x	x	n/a	n/a

Test description:		Key:	
Intended use tests A: Altitude B: Thermal cycling C: Vibration D: Shock	Reasonably foreseeable misuse tests E: External short-circuit F: Impact G: Crush H: Forced discharge I: Abnormal charging J: Free fall K: Thermal abuse L: Incorrect installation M: Overdischarge	Form s: cell or single cell battery m: multi cell battery Applicability x: applicable n/a: not applicable	

[a] Only one test shall be applied, test F or test G.

[b] Only applicable to CR17345, CR15H270, FR14505, FR10G445 and similar type batteries of a spiral construction that could be installed incorrectly and charged.

[c] Only applicable to CR17345, CR15H270, FR14505, FR10G445 and similar type batteries of a spiral construction that could be overdischarged.

[d] Test applies to the component cells.

6.1.2 Cautionary notice

WARNING: These tests call for the use of procedures which can result in injury if adequate precautions are not taken.

It has been assumed in the drafting of these tests that their execution is undertaken by appropriately qualified and experienced technicians using adequate protection.

6.1.3 Ambient temperature

Unless otherwise specified, the tests shall be carried out at an ambient temperature of 20 °C ± 5 °C.

6.1.4 Parameter measurement tolerances

The overall accuracy of controlled or measured values, relative to the specified or actual parameters, shall be within the following tolerances:

a) ± 1 % for voltage;
b) ± 1 % for current;
c) ± 2 °C for temperature;
d) ± 0,1 % for time;
e) ± 1 % for dimensions;
f) ± 1 % for capacity.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

6.1.5 Predischarge

Where a test requires predischarge, the test cells or batteries shall be discharged to the respective depth of discharge on a resistive load with which the rated capacity is obtained or at a current specified by the manufacturer.

6.1.6 Additional cells

Where additional cells are required to perform a test, they shall be of the same type and, preferably, from the same production lot as the test cell.

6.2 Evaluation of test criteria

6.2.1 Short-circuit

A short-circuit is considered to have occurred during a test if the open circuit voltage of the cell or battery immediately after the test is less than 90 % of its voltage prior to the test. This requirement is not applicable to test cells and batteries in fully discharged states.

6.2.2 Excessive temperature rise

An excessive temperature rise is considered to have occurred during a test if the external case temperature of the test cell or battery rises above 170 °C.

6.2.3 Leakage

Leakage is considered to have occurred during a test if there is visible escape of electrolyte or other material from the test cell or battery, or the loss of material (except battery casing, handling devices or labels) from the test cell or battery such that the mass loss exceeds the limits in Table 3.

In order to quantify mass loss $\Delta m / m$, the following equation is provided:

$$\Delta m / m = \frac{m_1 - m_2}{m_1} \times 100\ \%$$

where

m_1 is the mass before a test;

m_2 is the mass after that test.

Table 3 – Mass loss limits

Mass of cell or battery m	Mass loss limit $\Delta m / m$
m < 1 g	0,5 %
1 g ≤ m ≤ 75 g	0,2 %
m > 75 g	0,1 %

6.2.4 Venting

Venting is considered to have occurred if, during a test, an excessive build up of internal gas pressure escapes from a cell or battery through a pressure relief feature designed for this purpose. This gas may include entrapped materials.

6.2.5 Fire

A fire is considered to have occurred if, during a test, flames are emitted from the test cell or battery.

6.2.6 Rupture

A rupture is considered to have occurred if a cell container or battery case has mechanically failed, resulting in expulsion of gas or spillage of liquids but not forcible ejection of solid materials.

6.2.7 Explosion

An explosion is considered to have occurred if a cell container or battery case opens violently and solid components are forcibly ejected. During cell or component cell testing, ejection of internal components is acceptable. Energy of ejected components shall be limited. If required, it may be measured as follows:

a) It will not penetrate a wire mesh screen (annealed aluminium wire with a diameter of 0,25 mm and grid density of 6 to 7 wires per cm) placed 25 cm away from the cell; or

b) It can be measured by a method demonstrated to be equivalent to the one described in a).

6.3 Tests and requirements – Overview

This document provides safety tests for intended use (tests A to D) and reasonably foreseeable misuse (tests E to M). Table 4 contains an overview of the tests and requirements for intended use and reasonably foreseeable misuse.

Table 4 – Tests and requirements

Test number		Designation	Requirements
Intended use tests	A	Altitude	NL, NV, NC, NR, NE, NF
	B	Thermal cycling	NL, NV, NC, NR, NE, NF
	C	Vibration	NL, NV, NC, NR, NE, NF
	D	Shock	NL, NV, NC, NR, NE, NF
Reasonably foreseeable misuse tests	E	External short-circuit	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Crush	NT, NE, NF
	H	Forced discharge	NE, NF
	I	Abnormal charging	NE, NF
	J	Free fall	NV, NE, NF
	K	Thermal abuse	NE, NF
	L	Incorrect installation	NE, NF
	M	Overdischarge	NE, NF

Tests A through E shall be conducted in sequence on the same cell or battery.
Tests F and G are provided as alternatives. Only one of them shall be conducted.

Key

NC: No short-circuit
NE: No explosion
NF: No fire
NL: No leakage
NR: No rupture
NT: No excessive temperature rise
NV: No venting

See 6.2 for a detailed description of the test criteria.

6.4 Tests for intended use

6.4.1 Test A: Altitude

a) Purpose

This test simulates air transport under low pressure conditions.

b) Test procedure

Test cells and batteries shall be stored at a pressure of 11,6 kPa or less for at least 6 h at ambient temperature.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.2 Test B: Thermal cycling

a) Purpose

This test assesses cell and battery seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

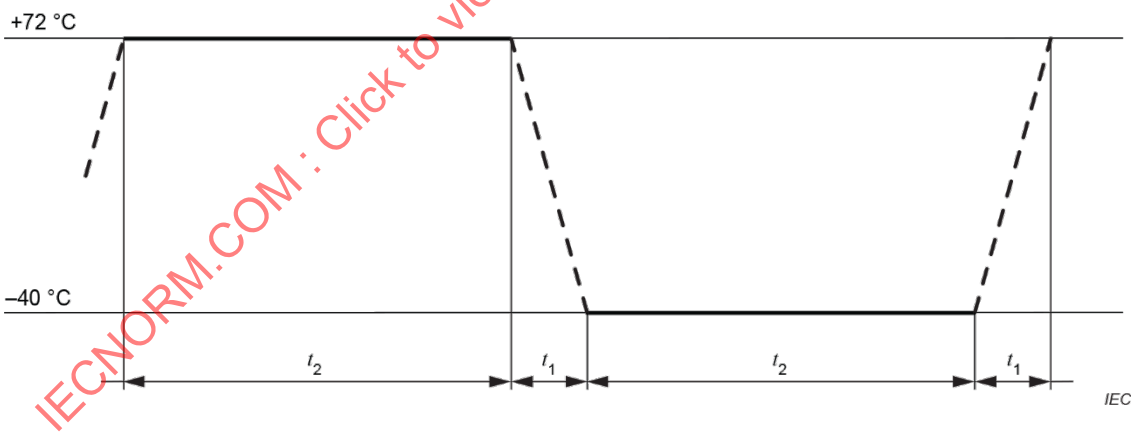
b) Test procedure

Test cells and batteries shall be stored for at least 6 h at a test temperature of 72 °C, followed by storage for at least 6 h at a test temperature of –40 °C. The maximum time for transfer to each temperature shall be 30 min. Each test cell and battery shall undergo this procedure 10 times. This is then followed by storage for at least 24 h at ambient temperature.

For large cells and batteries the duration of exposure to the test temperatures shall be at least 12 h instead of 6 h.

Figure 1 shows a diagram of one of ten thermal cycles.

The test shall be conducted using the test cells and batteries previously subjected to the altitude test.



Key

t_1 ≤ 30 min

t_2 ≥ 6 h (12 h for large cells and batteries)

~~NOTE The figure shows one of ten cycles~~

Figure 1 – Thermal cycling procedure

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.3 Test C: Vibration

a) Purpose

This test simulates vibration during transport. The test condition is based on the range of vibrations as given by ICAO [2].

b) Test procedure

Test cells and batteries shall be firmly secured to the platform of the vibration machine without distorting them and in such a manner as to faithfully transmit the vibration. Test cells and batteries shall be subjected to sinusoidal vibration according to Table 5 which shows a different upper acceleration amplitude for large batteries. This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

The test shall be conducted using the test cells and batteries previously subjected to the thermal cycling test.

Table 5 – Vibration profile (sinusoidal)

Frequency range		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
From	To				
f_1 = 7 Hz	f_2	a_1 = 1 g_n	15 min	X	12
f_2	f_3	s = 0,8 mm		Y	12
f_3	f_4 = 200 Hz	a_2		Z	12
and back to f_1 = 7 Hz				Total	36

Key

f_1, f_4 lower and upper frequency

f_2, f_3 cross-over frequencies;

f_2 ≈ 17,62 Hz; and

f_3 ≈ 49,84 Hz, except for large batteries, where f_3 ≈ 24,92 Hz

a_1, a_2 acceleration amplitude; a_2 = 8 g_n, except for large batteries, where a_2 = 2 g_n

s displacement amplitude

NOTE 1 Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0,8 mm corresponds to a peak-to-peak displacement of 1,6 mm.

NOTE 2 g_n = 9,806 65 m / s^2

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.4 Test D: Shock

a) Purpose

This test simulates rough handling during transport.

b) Test procedure

Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test cell or battery. Each test cell or battery shall be subjected to 3 shocks in each direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks. For each shock, the parameters given in Table 6 shall be applied.

Table 6 – Shock parameters

	Waveform	Peak acceleration	Pulse duration	Number of shocks per half axis
Cells or batteries except large ones	Half sine	150 g_n	6 ms	3
Large cells or batteries	Half sine	50 g_n	11 ms	3
NOTE g_n = 9,806 65 m / s^2				

For lithium primary batteries with a mass ~~in excess of 12 kg~~ of more than 4,482 kg, the test method of test T-4 in IEC 62281 may be used.

The test shall be conducted using the test cells and batteries previously subjected to the vibration test.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.5 Tests for reasonably foreseeable misuse

6.5.1 General

The test methods described hereafter were developed for batteries specified in IEC 60086-2. However, they shall also be applied to batteries which are not specified therein. For batteries not specified in IEC 60086-2, additional requirements apply which are described in Annex G.

6.5.2 Test E: External short-circuit

a) Purpose

This test simulates conditions resulting in an external short-circuit.

b) Test procedure

The test cell or battery shall be stabilized at an external case temperature of 55 °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at 55 °C. This short-circuit condition is continued for at least 1 h after the cell or battery external case temperature has returned to 55 °C.

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-5 in IEC 62281 may be used.

The test sample shall be observed for a further 6 h.

The test shall be conducted using the test samples previously subjected to the shock test.

c) Requirements

There shall be no excessive temperature rise, no rupture, no explosion and no fire during this test and within the 6 h of observation.

6.5.3 Test F: Impact

a) Purpose

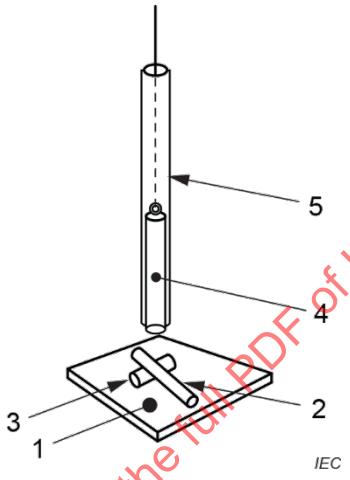
This test simulates mechanical abuse from an impact that can result in an internal short circuit.

b) Test procedure

The impact test is applicable to cylindrical cells not less than 18 mm in diameter.

The test cell or component cell is placed on a flat smooth surface. A stainless steel bar (type 316 or equivalent) with a diameter of 15,8 mm ± 0,1 mm and a length of at least 60 mm or of the longest dimension of the cell, whichever is greater, is placed across the centre of the test sample. A mass of 9,1 kg ± 0,1 kg is dropped from a height of 61 cm ± 2,5 cm at the intersection of the bar and the test sample in a controlled manner using a near frictionless, vertical sliding track or channel with minimal drag on the falling mass. The vertical track or channel used to guide the falling mass shall be oriented 90 degrees from the horizontal supporting surface.

The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the stainless steel bar lying across the centre of the test sample (see Figure 2).



NOTE The figure shows a flat smooth surface (1) and a stainless steel bar (2) which is placed across the centre of the test sample (3). A mass (4) is dropped at the intersection in a controlled manner using a vertical sliding channel (5).

Figure 2 – Example of a test set-up for the impact test

Each test cell or component cell shall be subjected to one impact only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test cells or component cells that have not been previously subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.4 Test G: Crush

a) Purpose

This test simulates mechanical abuse from a crush that can result in an internal short circuit.

b) Test procedure

The crush test is applicable to prismatic, flexible[2], coin cells and cylindrical cells less than 18 mm in diameter.

A cell or component cell is to be crushed between two flat surfaces. The crushing is to be gradual with a speed of approximately 1,5 cm/s at the first point of contact. The crushing is to be continued until one of the three conditions below is reached:

[2] The term “flexible cell” is used in this document in place of the term “pouch cell” which is used in [21]. It is also used in place of the terms “cell with a laminate film case” and “laminate film cell”.

1) The applied force reaches 13 kN ± 0,78 kN;

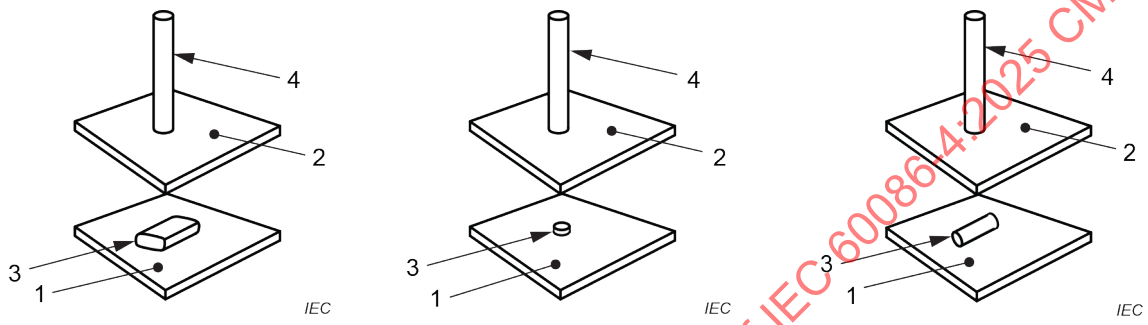
EXAMPLE: The force can be applied by a hydraulic ram with a 32 mm diameter piston until a pressure of 17 MPa is reached on the hydraulic ram.

2) The voltage of the cell drops by at least 100 mV; or

3) The cell is deformed by 50 % or more of its original thickness.

As soon as one of the above conditions has been obtained, the pressure shall be released.

A prismatic or flexible cell shall be crushed by applying the force to the side with the largest surface area. A coin cell shall be crushed by applying the force on its flat surfaces. For cylindrical cells, the crush force shall be applied perpendicular to the longitudinal axis. See Figure 3.



a) Prismatic or flexible cell **b) Coin cell** **c) Cylindrical cell**

NOTE The figures show two flat surfaces (1 and 2) with batteries (3) of different shapes placed between them for crushing, using a piston (4).

Figure 3 – Examples of a test set-up for the crush test

Each test cell or component cell is to be subjected to one crush only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test cells or component cells that have not previously been subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.5 Test H: Forced discharge

a) Purpose

This test evaluates the ability of a cell to withstand a forced discharge condition.

b) Test procedure

Each cell shall be force discharged at ambient temperature by connecting it in series with a 12 V direct current power supply at an initial current equal to the maximum continuous discharge current specified by the manufacturer.

The specified discharge current is obtained by connecting a resistive load of appropriate size and rating in series with the test cell and the direct current power supply. Each cell shall be force discharged for a time interval equal to its rated capacity divided by the initial test current.

This test shall be conducted with fully discharged test cells or component cells that have not previously been subjected to other tests.

c) Requirements

There shall be no explosion and no fire during this test and within 7 days after the test.

6.5.6 Test I: Abnormal charging

a) Purpose

This test simulates the condition when a battery is fitted within a device and is exposed to a reverse (charging) current from an external power supply, for example memory back-up equipment with a defective diode (see 7.1.2). The test condition is based upon UL 1642 [19].

NOTE This test does not take into account the case where a battery is misused by inserting it into a battery charger (inadvertent confusion with a rechargeable battery).

b) Test procedure

Each test battery shall be subjected to a charging current of three times the abnormal charging current I_c specified by the battery manufacturer by connecting it in opposition to a DC power supply. Unless the power supply allows for setting the current, the specified charging current shall be obtained by connecting a resistor of the appropriate size and rating in series with the battery.

The test duration shall be calculated using the formula:

$$t_d = 2{,}5 \times C_n / (3 \times I_c)$$

where

t_d is the test duration. In order to expedite the test, it is permitted to adjust the test parameters such that t_d does not exceed 7 days;

C_n is the nominal capacity declared by the manufacturer;

I_c is the abnormal charging current declared by the manufacturer for this test.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.7 Test J: Free fall

a) Purpose

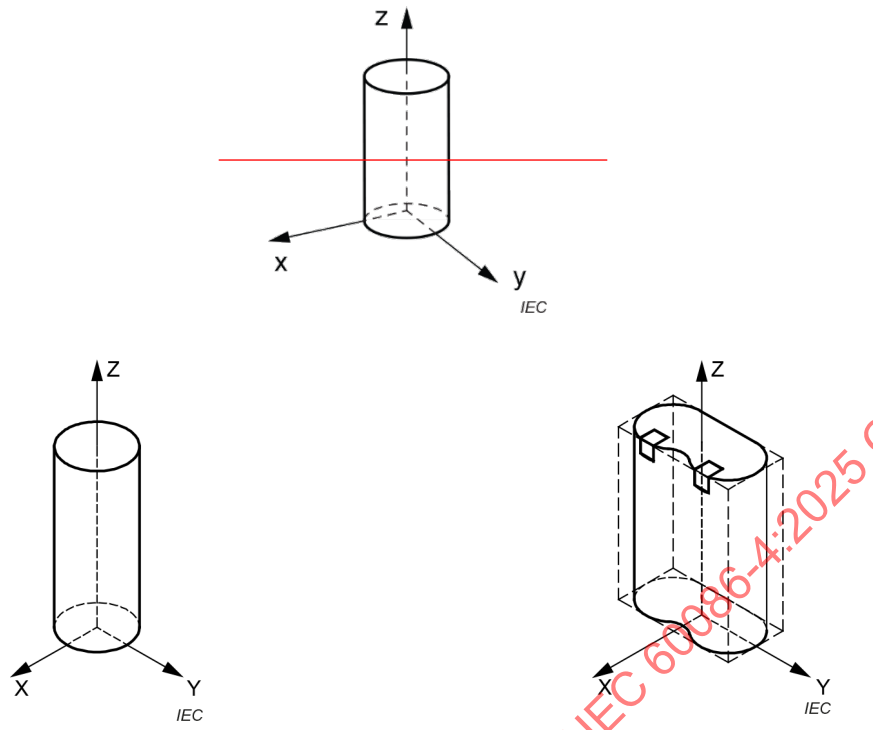
This test simulates the situation when a battery is accidentally dropped. The test condition is based upon IEC 60068-2-31 [7].

b) Test procedure

The test batteries shall be dropped from a height of 1 m onto a concrete surface. Each test battery shall be dropped six times, a prismatic battery once from each of its six faces, a round battery twice in each of the three axes shown in Figure 4a). The test batteries shall be stored for 1 h afterwards.

NOTE The term "prismatic" is used assuming that the battery shape can be fitted to a rectangular parallelepiped as shown in Figure 4b).

The test shall be conducted with undischarged test cells and batteries.



a) Round cell or battery

b) Prismatic cell or battery

Figure 4 – Axes for free fall

c) Requirements

There shall be no venting, no explosion and no fire during this test and within the 1 h of observation.

6.5.8 Test K: Thermal abuse

a) Purpose

This test simulates the condition when a battery is exposed to an extremely high temperature.

b) Test procedure

A test battery shall be placed in an oven and the temperature raised at a rate of 5 °C/min to a temperature of 130 °C at which the battery shall remain for 10 min.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.9 Test L: Incorrect installation

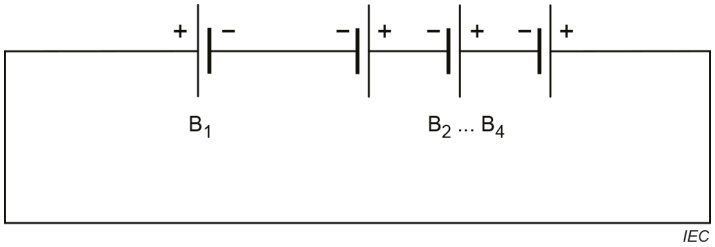
a) Purpose

This test simulates the condition when one single cell battery in a set is reversed.

NOTE Primary batteries are not designed to be charged. However, reversed installation of a battery in a series of three or more, as well as insertion into a battery charger, exposes the battery to a charging condition. Although cylindrical batteries are designed to relieve excessive internal pressure, in some instances an explosion might not be precluded.

b) Test procedure

A test battery is connected in series with three undischarged additional single cell batteries of the same brand and type in such a way that the terminals of the test battery are connected in reverse. The resistance of the interconnecting circuit shall be no greater than 0,1 Ω. The circuit shall be completed for 24 h or until the battery case temperature has returned to ambient (see Figure 5).



Key

B_1	Test cell
$B_2 \ldots B_4$	Additional cells, undischarged

Figure 5 – Circuit diagram for incorrect installation

c) Requirements

There shall be no explosion and no fire during this test.

6.5.10 Test M: Overdischarge 3

a) Purpose

This test simulates the condition when one discharged single cell battery is connected in series with other undischarged single cell batteries. The test further simulates the use of batteries in motor powered appliances or high intensity lighting applications where, in general, currents ~~over~~ up to 1 A are required.

NOTE CR17345, CR15H270, FR14505 and FR10G445 batteries are widely used in motor powered appliances or high intensity lighting applications where currents ~~over~~ up to 1 A are required. The current for non standardized batteries might be different.

b) Test procedure

Each test battery shall be predischarged to 50 % depth of discharge. ~~It shall then be connected in series with three undischarged additional single cell batteries of the same type.~~ A CR-type battery shall then be connected in series with one undischarged additional single cell battery of the same type. An FR-type battery shall be connected in series with three undischarged additional single cell batteries of the same type.

A resistive load ~~R_1~~ R is connected in series with the assembly of n batteries in Figure 6 where ~~R_1~~ R and n are taken from Table 7.

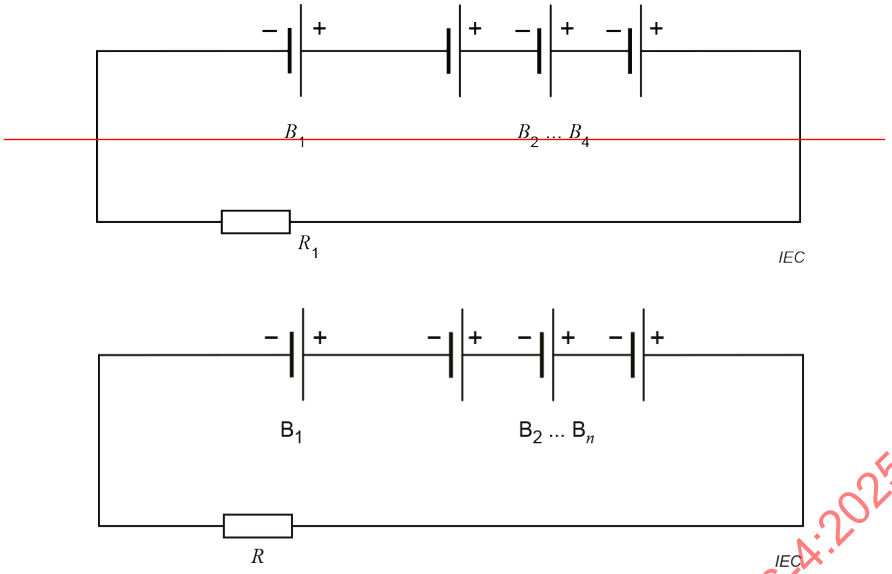
The test shall be continued for 24 h or until the battery case temperature has returned to ambient.

The test shall be repeated with ~~75 % predischarged~~ fully discharged test batteries.

Table 7 – Resistive load for overdischarge

~~Battery type~~	~~Resistive load R_1 Ω~~
~~CR17345~~	~~8,20~~
~~CR15H270~~	~~8,20~~
~~FR14505~~	~~3,60~~
~~FR10G445~~	~~3,60~~
~~NOTE Table to be modified or expanded when additional batteries of a spiral construction are standardized.~~ ~~EXAMPLE When CR17345 and CR15H270 batteries were standardized, R_1 was determined from the end-voltage of the assembly in Figure 6, using the formula~~ ~~$R = 4 \times 2{,}0\ V / 1\ A$~~ ~~where~~ ~~2,0 V is the end-voltage taken from the specification tables in IEC 60086-2; and 1 A is the test current.~~ ~~R_1 was then found by rounding R to the nearest value in Table 4 of IEC 60086-1:2015.~~	

Battery type	Total number of single cell batteries in the assembly n	End-point voltage V	Resistive load R Ω
CR17345	2	1,8	3,60
CR15H270			
FR14505	4	0,9	
FR10G445			
NOTE Table to be modified or expanded when additional batteries of a spiral construction are standardized. EXAMPLE The resistive load R for CR17345 and CR15H270 batteries was determined from the end-point voltage of each cell under the high intensity lighting test and the total number of cells in the test assembly in Figure 6 using the formula $R = 2 \times 1{,}8\ V / 1\ A$			



Key

B_1 Test battery, 50 % predischarged and, in separate tests, ~~75 % predischarged~~ fully discharged

B_2... ~~B_4~~B_n Additional batteries, undischarged. The number of additional batteries is n-1

~~R_1~~R Resistive load

Figure 6 – Circuit diagram for overdischarge

c) Requirements

There shall be no explosion and no fire during this test.

6.6 Information to be given in the relevant specification

When this document is referred to in a relevant specification, the parameters given in Table 8 shall be given in so far as they are applicable:

Table 8 – Parameters to be specified

Item	Parameters	Subclause
a)	Predischarge current or resistive load and end-point voltage specified by the manufacturer	6.1.5
b)	Method to measure the energy of an explosion, if any.	6.2.7
c)	Shape: prismatic, flexible, coin or cylindrical; Diameter: less than 18 mm or not less than 18 mm.	6.5.3 and 6.5.4
d)	Maximum continuous discharge current specified by the manufacturer for test H NOTE 1 Forced discharge of a cell can occur when it is connected in series with other cells and when it is not protected with a bypass diode.	6.5.5
e)	Rated capacity specified by the manufacturer for test H	6.5.5
f)	Abnormal charging current declared by the manufacturer for test I NOTE 2 Abnormal charging of a cell can occur when it is connected in series with other cells and one cell is reversed or when it is connected in parallel with a power supply and the protective devices do not operate correctly.	6.5.6
g)	Nominal capacity specified by the manufacturer	6.5.6
h)	Normal reverse current declared by the manufacturer which can be applied to the battery during its operating life NOTE 3 Normal reverse current flow through a cell can occur when it is connected in parallel with a power supply and the protective devices are operating properly.	7.1.2

6.7 Evaluation and report

When a report is issued, the following list of items should be considered:

a) name and address of the test facility;
b) name and address of applicant (where appropriate);
c) a unique test report identification;
d) the date of the test report;
e) design characteristics of the test cells or batteries according to 4.1;
f) test descriptions and results, including the parameters according to 6.6;
g) type of the test sample(s): cell, component cell, battery or battery assembly;
h) weight of the test sample(s);
i) lithium content of the sample(s);
j) a signature with name and status of the signatory.

It is not necessary to issue a new report unless new type testing is required, see 5.1.

7 Information for safety

7.1 Safety precautions during design of equipment

7.1.1 General

See also Annex B for guidelines for designers of equipment using lithium batteries.

7.1.2 Charge protection

When incorporating a primary lithium battery into a circuit powered by an independent main power source, protective devices shall be used in order to prevent charging the primary battery from the main power source, for example:

a) a blocking diode and a current limiting resistor (see Figure 7a);
b) two series blocking diodes (see Figure 7b);
c) circuits with a similar blocking function based on two or more independent protective devices;

provided that the first protective device is capable of limiting the charging current through the lithium battery to the normal reverse current specified by the manufacturer which can be applied to the battery during its operating life, while the second protective device is capable of limiting the charging current to the abnormal charging current specified by the battery manufacturer and used for conduction of test I, Abnormal charging. The circuit shall be so designed that at least one of these protective devices remains operational when any one component of the circuit fails.

a) Diode and resistor **b) Two diodes**

Figure 7 – Examples of wiring for charge protection

7.1.3 Parallel connection

Parallel connection should be avoided when designing battery compartments. However, if required, the battery manufacturer shall be contacted for advice.

7.2 Precautions during handling of batteries

When used correctly, lithium batteries provide a safe and dependable source of power. However, if they are misused or abused, leakage, venting or, in extreme cases, explosion and/or fire can result.

a) Keep batteries out of the reach of children

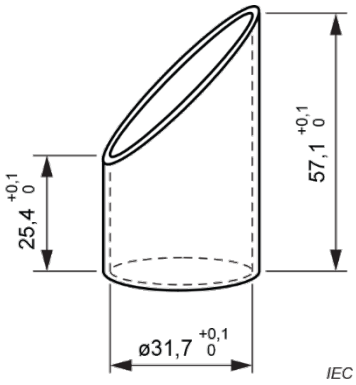
In particular, keep batteries which are considered swallowable out of the reach of children, particularly those batteries fitting within the limits of the ingestion gauge as defined in Figure 8. In case of ingestion of a cell or battery, seek medical assistance promptly. Swallowing coin cells or batteries can cause chemical burns, perforation of soft tissue, and, in severe cases, can cause death. They need to be removed immediately if swallowed. See Figure 9 for an example of appropriate warning text.

Warning text similar to Figure 9 may be used for safety information about battery handling. For cautionary advice and symbols to be printed on batteries and battery packaging refer to Clause 9.

NOTE 1 ~~Refer to E.1 in Annex E for more details.~~Child-resistant packaging according to Annex E is intended to help keep coin cells out of the reach of children before use.

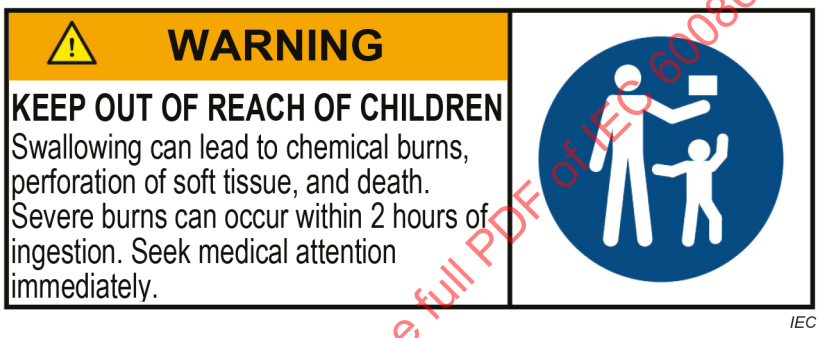
NOTE 2 Refer to [13] for general information on hazards from batteries.

Dimensions in millimetres



[SOURCE: ISO 8124-1 [18]]

Figure 8 – Ingestion gauge



NOTE This product safety label is compliant with [16].

Figure 9 – Example for warning against swallowing, particularly coin cell batteries

b) Do not allow children to replace batteries without adult supervision

c) Always insert batteries correctly with regard to polarity (+ and –) marked on the battery and the equipment

When batteries are inserted in reverse they might be short-circuited or charged. This can cause overheating, leakage, venting, rupture, explosion, fire and personal injury.

d) Do not short-circuit batteries

When the positive (+) and negative (–) terminals of a battery are in electrical contact with each other, the battery becomes short-circuited. For example loose batteries in a pocket with keys or coins, can be short-circuited. This can result in venting, leakage, explosion, fire and personal injury.

e) Do not charge batteries

Attempting to charge a non-rechargeable (primary) battery can cause internal gas and/or heat generation resulting in leakage, venting, explosion, fire and personal injury.

f) Do not force discharge batteries

When batteries are force discharged by means of an external power source, the voltage of the battery will be forced below its design capability and gases will be generated inside the battery. This can result in leakage, venting, explosion, fire and personal injury.

g) Do not mix new and used batteries or batteries of different types or brands

When replacing batteries, replace all of them at the same time with new batteries of the same brand and type. When batteries of different brand or type are used together or new and used batteries are used together, some batteries might be over-discharged / force discharged due to a difference of voltage or capacity. This can result in leakage, venting, explosion or fire, and can cause personal injury.

h) Exhausted batteries should be immediately removed from equipment and properly disposed of

When discharged batteries are kept in the equipment for a long time, electrolyte leakage can occur causing damage to the equipment and/or personal injury.

i) Do not heat batteries

When a battery is exposed to heat, leakage, venting, explosion or fire can occur and cause personal injury.

j) Do not weld or solder directly to batteries

The heat from welding or soldering directly to a battery can cause leakage, venting, explosion or fire, and can cause personal injury.

k) Do not dismantle batteries

When a battery is dismantled or taken apart, contact with the components can be harmful and can cause personal injury or fire.

l) Do not deform batteries

Batteries should not be crushed, punctured or otherwise mutilated. Such abuse can cause leakage, venting, explosion or fire, and can cause personal injury.

m) Do not dispose of batteries in fire

When batteries are disposed of in fire, the heat build-up can cause explosion and/or fire and personal injury. Do not incinerate batteries except for approved disposal in a controlled incinerator.

n) A lithium battery with a damaged container should not be exposed to water

Lithium metal in contact with water can produce hydrogen gas, fire, explosion and/or cause personal injury.

o) Do not encapsulate and/or modify batteries

Encapsulation or any other modification to a battery can result in blockage of the pressure relief mechanism(s) and subsequent explosion and personal injury. Advice from the battery manufacturer should be sought if it is considered necessary to make any modification.

p) Store unused batteries in their original packaging away from metal objects. If already unpacked, do not mix or jumble batteries

Unpacked batteries could get jumbled or get mixed with metal objects such as keys, coins, etc. This can cause battery short-circuiting which can result in leakage, venting, explosion or fire, and personal injury. One of the best ways to prevent this from happening is to store unused batteries in their original packaging.

q) Remove batteries from equipment if it is not to be used for an extended period of time unless it is for emergency purposes

It is advantageous to remove batteries immediately from equipment which has ceased to function satisfactorily, or when a long period of disuse is anticipated (e.g. camcorders, digital

cameras, photoflash, etc.). Although most lithium batteries on the market today are highly leak resistant, a battery that has been partially or completely exhausted might be more prone to leak than one that is unused.

7.3 Additional information for safety of coin cells 4

Additional information for safety of coin cells is provided by consumer safety organisations as well as battery manufacturers' associations. When searching for such information, it should be noted that the term "coin cell" is not used in most languages other than English, and the distinction between a cell and a battery is often not made in the literature. Therefore, the term "lithium button cell" has been proposed as an alternative to the term "coin cell" and the terms "coin battery" and "lithium button battery" have been proposed as alternatives to the terms "coin cell" and "lithium button cell". The terms "coin cell" and "coin battery" are only used in English. In languages other than English, the term "lithium button cell" is used instead of the term "coin cell" and the term "lithium button battery" is used instead of the term "coin battery".

7.4 Packaging

The packaging shall be adequate to avoid mechanical damage during transport, handling and stacking. The materials and packaging design shall be chosen so as to prevent the development of unintentional electrical contact, short-circuit, shifting and corrosion of the terminals, and afford some protection from the environment.

7.5 Handling of battery cartons

Battery cartons should be handled with care. Rough handling might result in batteries being short-circuited or damaged. This can cause leakage, explosion, or fire.

7.6 Transport

7.6.1 General

Regulations concerning international transport of lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods [20].

Regulations for transport are subject to change. For the transport of lithium batteries, the latest editions of the following regulations should be consulted.

Testing requirements are defined in the UN Manual of Tests and Criteria [21]. As regulations are subject to change, the latest editions should be consulted.

For reference, transportation tests are also given in IEC 62281.

7.6.2 Air transport

Regulations concerning air transport of lithium batteries are specified in the Technical Instructions for the Safe Transport of Dangerous Goods by Air published by the International Civil Aviation Organization (ICAO) [2] and in the Dangerous Goods Regulations published by the International Air Transport Association (IATA) [1].

7.6.3 Sea transport

Regulations concerning sea transport of lithium batteries are specified in the International Maritime Dangerous Goods (IMDG) Code published by the International Maritime Organization (IMO) [12].

7.6.4 Land transport

Regulations concerning road and railroad transport are specified on a national or multilateral basis. While an increasing number of regulators adopt the UN Model Regulations [20], it is recommended that country-specific transport regulations be consulted before shipping.

7.7 Display and storage

a) Store batteries in well ventilated, dry and cool conditions

High temperature or high humidity can cause deterioration of the battery performance and/or surface corrosion.

b) Do not stack battery cartons on top of each other exceeding a specified height

If too many battery cartons are stacked, batteries in the lowest cartons might be deformed and electrolyte leakage can occur.

c) Avoid storing or displaying batteries in direct sun or in places where they get exposed to rain

When batteries get wet, their insulation resistance might be impaired and self-discharge and corrosion can occur. Heat can cause deterioration.

d) Store and display batteries in their original ~~packing~~ packaging

When batteries are unpacked and mixed they can be short-circuited or damaged.

See Annex C for additional details.

7.8 Disposal

Batteries may be disposed of via communal refuse arrangements provided no local rules to the contrary exist.

During transport, storage and handling for disposal, the following precautions should be considered:

a) Do not dismantle batteries

Some ingredients of lithium batteries might be flammable or harmful. They can cause injuries, fire, rupture or explosion.

b) Do not dispose of batteries in fire except under conditions of approved and controlled incineration

Lithium burns violently. Lithium batteries can explode in a fire. Combustion products from lithium batteries can be toxic and corrosive.

c) Store collected batteries in a clean and dry environment out of direct sunlight and away from extreme heat

Dirt and wetness might cause short-circuits and heat. Heat might cause leakage of flammable gas. This can result in fire, rupture or explosion.

d) Store collected batteries in a well-ventilated area

Used batteries might contain a residual charge. If they are short-circuited, abnormally charged or force discharged, leakage of flammable gas might be caused. This can result in fire, rupture or explosion.

e) Do not mix collected batteries with other materials

Used batteries might contain residual charge. If they are short-circuited, abnormally charged or force discharged, the generated heat can ignite flammable wastes such as oily rags, paper or wood and cause a fire.

f) Protect battery terminals

Protection of terminals should be considered by providing insulation, particularly for those batteries with a high voltage. Unprotected terminals might cause short-circuits, abnormal charging and forced discharge. This can result in leakage, fire, rupture or explosion.

8 Instructions for use

a) Always select the correct size and type of battery most suitable for the intended use. Information provided with the equipment to assist correct battery selection should be retained for reference.

b) Replace all batteries of a set at the same time.

c) Clean the battery contacts and also those of the equipment prior to battery installation.

d) Ensure that the batteries are installed correctly with regard to polarity (+ and –).

e) Remove exhausted batteries promptly.

9 Marking and packaging

9.1 General

~~With the exception of swallowable batteries (see 9.2), each battery~~ In general, batteries shall be marked with the following information:

a) designation, IEC or common;

b) expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code;

c) polarity of the positive (+) terminal;

d) nominal voltage;

e) name or trademark of the manufacturer or supplier;

f) cautionary advice.

~~See Table 9 under "General" for a summary of the marking requirements.~~

9.2 Marking of batteries too small to accommodate all markings

Some batteries have a surface too small to accommodate all markings shown in 9.1. For these batteries the designation 9.1 a) and the polarity 9.1 c) shall be marked on the battery, while all other markings shown in 9.1 may be given on the immediate packaging instead of on the battery.

See Table 9 for a summary of the marking requirements.

9.3 Additional requirements for swallowable coin cells and batteries

For swallowable coin cells and batteries, i.e. those that fit entirely within the ingestion gauge (Figure 8), ~~the designation 9.1 a) and the polarity 9.1 c) shall be marked on the battery, while all other markings shown in 9.1 may be given on the immediate package. However, when batteries~~ that are intended for direct sale in consumer replaceable applications, caution for ingestion shall also be marked on the immediate ~~package~~ packaging:

a) caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F.

Swallowable coin cells and batteries that are intended for direct sale in consumer replaceable applications and have a diameter of 16 mm or more shall be packaged in:

b) child resistant packaging.

~~See Table 9 under "Swallowable" for a summary of the marking and packaging requirements.~~

~~Table 9 – Marking and packaging requirements~~

~~List item~~	~~General~~	~~Swallowable~~		
		~~d < 16 mm~~	~~16 mm ≤ d < 20 mm~~	~~d ≥ 20 mm~~
~~a) Designation, IEC or common~~	~~B~~	~~B~~	~~B~~	~~B~~
~~b) Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code~~	~~B~~			
~~c) Polarity of the positive (+) terminal~~	~~B~~	~~B~~	~~B~~	~~B~~
~~d) Nominal voltage~~	~~B~~			
~~e) Name or trade mark of the manufacturer or supplier~~	~~B~~			
~~f) Cautionary advice~~	~~B~~			
~~g) Caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F~~		~~P~~[1)]	~~P~~[1)]	~~B~~[1)] ~~+ P~~[1)]
~~h) Child resistant packaging~~	~~n/a~~	~~n/a~~	~~R~~	~~R~~
~~1) The transition period for this requirement is 2 years from the publication date of the fifth edition of this part of IEC 60086.~~				
~~Key:~~ ~~d: Diameter~~ ~~B: Marking required on cell / battery~~ ~~P: Marking required on immediate packaging~~ ~~R: Child resistant packaging~~ ~~n/a: Not applicable~~ ~~empty: Marking may appear on (cell / battery and/or) immediate packaging~~				

Refer to Table 10 for a summary of the additional marking and packaging requirements for swallowable coin cells and batteries.

Table 9 – Marking requirements

List item	General	Batteries too small to accommodate all markings
a) Designation, IEC or common	A	A
b) Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code	A	B
c) Polarity of the positive (+) terminal	A	A
d) Nominal voltage	A	B
e) Name or trademark of the manufacturer or supplier	A	B
f) Cautionary advice	A	B
Key: A: Shall be marked on the battery B: May be marked on the immediate packaging instead of on the battery		

Table 10 – Additional marking and packaging requirements for swallowable coin cells and batteries

List item	Swallowable coin cells and batteries		
	d < 16 mm	16 mm ≤ d < 20 mm	d ≥ 20 mm
a) Caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F	P	A 5 and P	A and P
b) Child resistant packaging	NR	R	R
Key: d: Diameter A: Shall be marked on the battery P: Shall be marked on the immediate packaging R: Required NR: Not required NOTE 1 The requirements in this table apply only when batteries are intended for direct sale in consumer replaceable applications (see 9.3). NOTE 2 The table does not include cylindrical cells and batteries because – although they may be swallowable – they would pass the oesophagus without causing harm.			

9.4 Safety pictograms

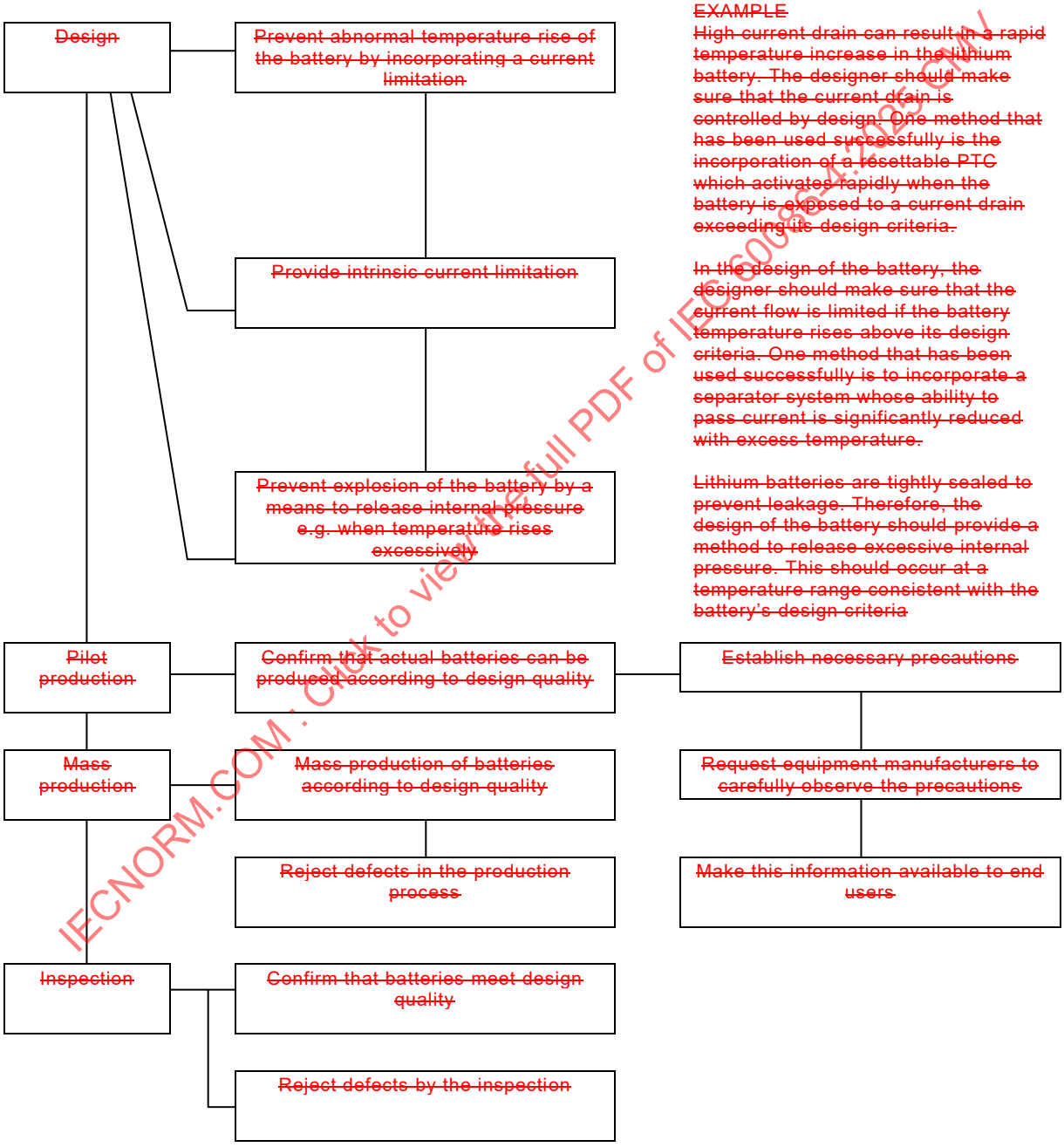
Safety pictograms that could be considered for use as an alternative to written cautionary advice are provided in Annex D.

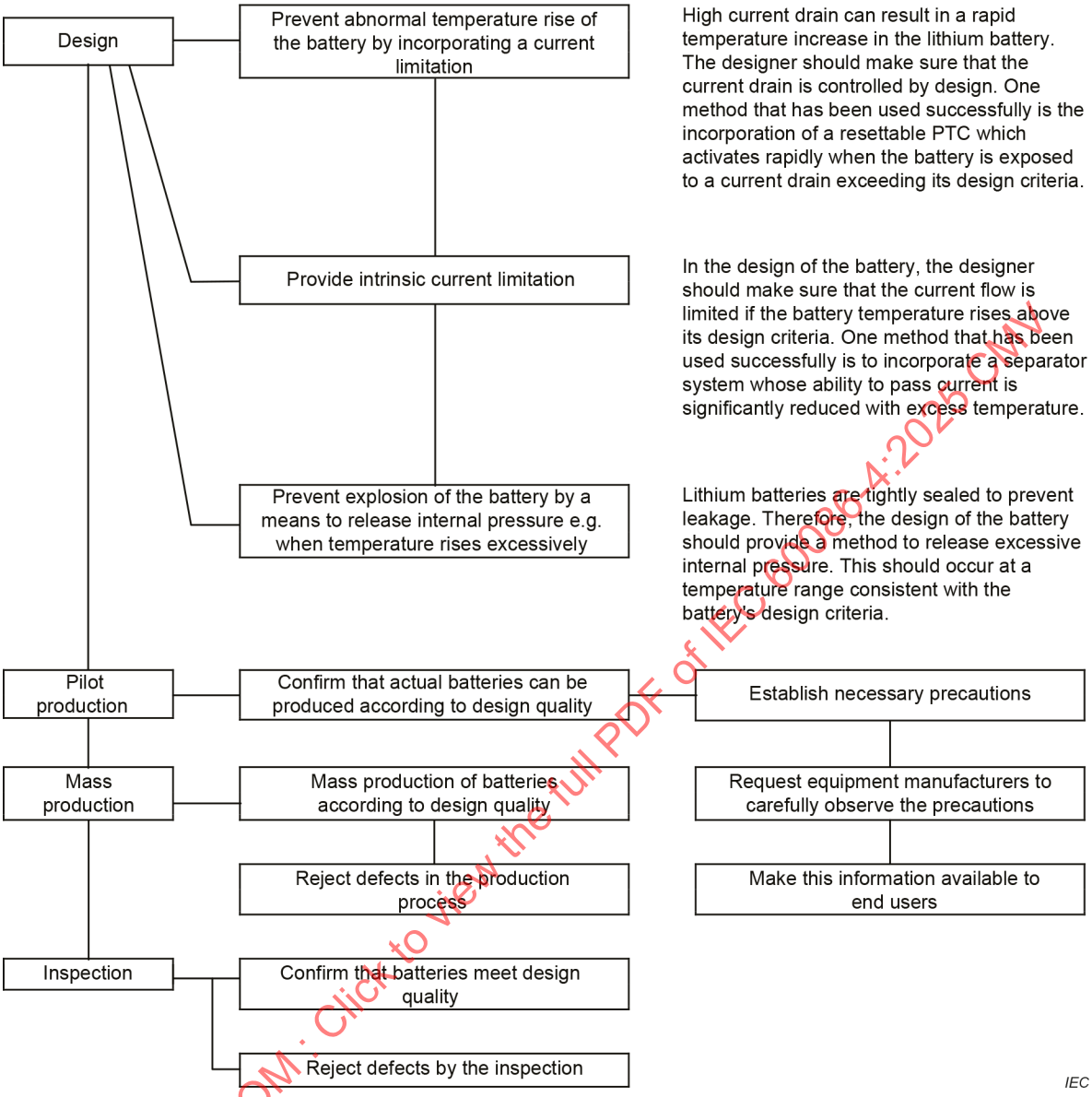
Annex A
(informative)

Guidelines for the achievement of safety of lithium batteries

The guidelines given in ~~Table A.1~~ Figure A.1 were followed during the development of high power batteries for consumer use. They are given here for information.

~~**Table A.1 – Battery design guidelines**~~





EXAMPLE

High current drain can result in a rapid temperature increase in the lithium battery. The designer should make sure that the current drain is controlled by design. One method that has been used successfully is the incorporation of a resettable PTC which activates rapidly when the battery is exposed to a current drain exceeding its design criteria.

In the design of the battery, the designer should make sure that the current flow is limited if the battery temperature rises above its design criteria. One method that has been used successfully is to incorporate a separator system whose ability to pass current is significantly reduced with excess temperature.

Lithium batteries are tightly sealed to prevent leakage. Therefore, the design of the battery should provide a method to release excessive internal pressure. This should occur at a temperature range consistent with the battery's design criteria.

Figure A.1 – Battery design guidelines

Annex B
(informative)

Guidelines for designers of equipment using lithium batteries

Table B.1 represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of primary lithium cells and batteries to equipment manufacturers and battery assemblers (see also IEC 60086-5:~~2016~~2021, Annex B ([8]), for guidelines for the design of battery compartments).

Table B.1 – Equipment design guidelines

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(1) When a lithium battery is used as main power source	(1.1) Selection of a suitable battery	Select most suitable battery for the equipment, taking note of its electrical characteristics	Battery might overheat
	(1.2) Number of batteries (series connection or parallel[a] connection) to be used and method of use	a) Multicell batteries (2CR5, CR-P2, 2CR13252 and others); one piece only	If the capacity of batteries in series connection is different, the battery with the lower capacity will be overdischarged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Cylindrical batteries (CR17345 and others); ~~less~~ no more than ~~three~~ two pieces	
		c) Coin type batteries (CR2016, CR2025, CR11108 and others); ~~less~~ no more than ~~three~~ two pieces	
		d) When more than one battery is used, different types should not be used in the same battery compartment	
		e) When batteries are used in parallel[a] protection against charging should be provided	If the voltages of batteries in parallel connection are different, the battery with the lower voltage will become charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(1.3) Design of battery circuit	a) Battery circuit should be isolated from any other power source	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Protective devices such as fuses should be incorporated in the circuit	Short-circuiting a battery can result in electrolyte leakage, overheating, rupture, explosion or fire
(2) When a lithium battery is used as back-up power source	(2.1) Design of battery circuit	The battery should be used in a separate circuit so that it is not force discharged or charged by the main power source	Battery might be over-discharged to reverse polarity or charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(2.2) Design of battery circuit for memory back-up application	When a battery is connected to the circuit of a main power source with the possibility of being charged, a protective circuit is necessary with a combination of diode and resistor. The accumulated amount of the leakage current of the diode should be below 2 % of the battery capacity during expected life time	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(3) Battery holder and battery compartment		a) Battery compartments should be designed so that if a battery is reversed, open circuit is achieved. Battery compartments should be clearly and permanently marked to show the correct orientation of batteries	Unless protection is provided against battery reversal, damage to equipment can occur from resultant electrolyte leakage, overheating, rupture, explosion or fire
		b) Battery compartments should be designed so that batteries other than the specified size cannot be inserted and make contact	Equipment might be damaged or might not operate
		c) Battery compartments should be designed to allow generated gases to escape	Battery compartments might be damaged when internal pressure of the battery becomes too high due to gas generation
		d) Battery compartments should be designed to be water proof	
		e) Battery compartments should be designed to be explosion proof when tightly sealed	
		f) Battery compartments should be isolated from heat generated by the equipment	Battery might be deformed and leak electrolyte due to excessive heat
		g) Battery compartments should be designed so that they cannot easily be opened by children	Children might remove batteries from the compartment and swallow them
(4) Contacts and terminals		a) Material and shape of contacts and terminals should be selected so that effective electric contact is maintained	Heat might generate at the contact due to insufficient connection
		b) Auxiliary circuit should be designed to prevent reverse installation of batteries	Equipment might be damaged or might not operate
		c) Contact and terminal should be designed to prevent reverse installation of batteries	Equipment might be damaged. Battery might cause electrolyte leakage, overheating, rupture, explosion or fire
		d) Direct soldering or welding to a battery should be avoided	Battery might leak, overheat, rupture, explode or catch fire

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(5) Indication of necessary precautions	(5.1) On the equipment 	a) Orientation of batteries (polarity) should be clearly indicated at the battery compartment	When a battery is inserted reverse and charged, it can result in electrolyte leakage, over-heating, rupture, explosion or fire
		b) The graphical symbol according to IEC 60417-5639 (2002-10) "rechargeable battery" [26] should be applied on battery chargers close to the battery compartment so as to indicate that only rechargeable batteries shall be inserted.	When non-rechargeable batteries are inserted in battery chargers, an explosion risk exists.
	(5.2) In the instruction manual 	a) Precautions for the proper handling of batteries should be indicated	Batteries might be mishandled and cause accidents
		b) The graphical symbol according to IEC 60417-5639 (2002-10) "rechargeable battery" [26] should be shown and explained in the instruction manuals of battery chargers so as to indicate that only rechargeable batteries shall be inserted.	When non-rechargeable batteries are inserted in battery chargers, an explosion risk exists. Batteries marked as "non-rechargeable" shall not be inserted.
		c) Instruction manuals generally should follow the principles layed down in [27].	
[a] See 7.1.3.			

Annex C
(informative)

Additional information on display and storage

This Annex C provides additional details concerning display and storage of lithium batteries to those already given in 7.7.

The storage area should be clean, cool, dry, ventilated and weatherproof.

For normal storage, the temperature should be between +10 °C and +25 °C and should never exceed +30 °C. Extremes of humidity (over 95 % and below 40 % relative humidity) for sustained periods should be avoided since they are detrimental to both batteries and ~~packings~~ packaging. Batteries should therefore not be stored next to radiators or boilers nor in direct sunlight.

Although the storage life of batteries at room temperature is excellent, storage is improved at lower temperatures provided that special precautions are taken. The batteries should be enclosed in special protective ~~packing~~ packaging (such as sealed plastic bags or variants) which should be retained to protect the batteries from condensation during the time they are warming to ambient temperature. Accelerated warming is harmful.

Batteries which have been cold-stored may be put into use after return to ambient temperature.

Batteries may be stored fitted in equipment or ~~packages~~ packaging, if determined suitable by the battery manufacturer.

The height to which batteries may be stacked is clearly dependent on the strength of the packaging. As a general rule, this height should not exceed 1,5 m for cardboard ~~packages~~ packaging or 3 m for wooden cases.

The above recommendations are equally valid for storage conditions during prolonged transit. Thus, batteries should be stored away from ship engines and not left for long periods in unventilated metal box cars (containers) during summer.

Batteries should be dispatched promptly after manufacture and in rotation to distribution centres and on to the users. In order that stock rotation (first in, first out) can be practised, storage areas and displays should be properly designed and packs adequately marked.

Annex D
(informative)

Safety pictograms

D.1 General

Cautionary advice to fulfil the marking requirements in this document has, on a historical basis, been in the form of written text. In recent years, there has been a growing trend toward the use of pictograms as a complementary or alternative means of product safety communication.

The objectives of this Annex D are: (1) to establish uniform pictogram recommendations that are tied to long-used and specific written text, (2) to minimize the proliferation of safety pictogram designs, and (3) to lay the foundation for the use of safety pictograms instead of written text to communicate product safety and cautionary statements.

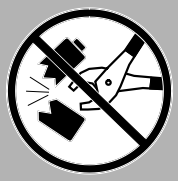
NOTE The design of these safety pictograms basically follows the design principles laid down in [15] and [17]. It was, however, adjusted to the limitations existing for battery marking.

D.2 Pictograms

The pictogram recommendations and cautionary advice are given in Table D.1.

Table D.1 – Safety pictograms

Reference	Safety pictogram	Cautionary advice
A		DO NOT CHARGE
B		DO NOT DEFORM OR DAMAGE
C		DO NOT DISPOSE OF IN FIRE
D		DO NOT INSERT INCORRECTLY

Reference	Safety pictogram	Cautionary advice
E		KEEP OUT OF REACH OF CHILDREN NOTE 1 See 7.2a) for critical safety information. NOTE 2 ~~This pictogram has been submitted to ISO TC 145 for standardisation in [18]~~ This pictogram is taken from ISO 7010-M055 (2020-11) [17], modified – arrow removed. The blue colour and the arrow of the ISO safety sign are not required. NOTE 3 See also Annex F.
F		DO NOT MIX DIFFERENT TYPES OR BRANDS
G		DO NOT MIX NEW AND USED
H		DO NOT OPEN OR DISMANTLE
I		DO NOT SHORT CIRCUIT
J		INSERT CORRECTLY
NOTE The grey shading highlights a white margin appearing when the ~~safety~~ pictogram is printed on coloured or black background.		

D.3 Instruction for use

The following instructions are provided for use of the safety pictograms.

a) Safety pictograms should be clearly legible. With the exception of pictogram E, they should have a diameter of 5 mm or larger.

b) Whilst colours are permitted, they should not detract from the information displayed. If colours are used, the circle and diagonal bar of pictograms A to D and F to I should be red and the background of pictograms E and J should be blue.

c) Not all of the safety pictograms need to be used together for a particular type or brand of battery. In particular, safety pictograms D and J are meant as alternatives for a similar purpose.

Annex E
(normative)

Child resistant packaging of coin cells

E.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its battery voltage ~~in excess of 2 V~~ causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

NOTE ~~Ingested button cells with less than 2 Volts do not exhibit the potential to cause severe chemical burns within a short time. If such cells have been ingested, established medical practice is to monitor them until they get past the oesophagus and then allow them to naturally pass through the digestive tract.~~

Accidental ingestion of coin batteries with a diameter of less than 16 mm is unlikely to cause serious chemical burns as they naturally pass through the oesophagus and gastrointestinal tract. It is established medical practice to monitor them until they get past the oesophagus and then allow them to naturally pass through the digestive tract.

This annex provides an approach for child resistant packaging of coin cells in order to help in preventing their accidental ingestion. This annex is not intended to supersede established national and international standards utilizing child panel package resistance testing, e.g. packaging requirements as specified in any of [23], [24], or [25].

E.2 Applicability

The following applies to consumer type coin cells with a diameter of 16 mm and larger.

a) Single cell packaging

The packaging for coin cells shall meet one of the following conditions:

i) Packaging requirements specified in any of [23], [24], or [25];

or

ii) The packaging strength shall be such that the packaging passes the tests described in E.3.

b) Multi-cell packaging

Each cell containment in a multi-cell packaging shall be in compliance with a) even when another cell containment is removed from the packaging.

E.3 Packaging tests

E.3.1 General

The following test methods were developed based on the analysis of the behaviour of children in a test where they were required to try and open coin cell packaging within a limited time. The tests shall be conducted by an instructed person or, alternatively, if necessary, using suitable equipment.

E.3.2 Test items

a) Bending test

Hold the packaging with the fingers of one hand and hold the cell with the fingers of the other hand. Bend the packaging close to the battery until one hand touches the other hand as shown in Figure E.1. ~~This is a guide for The bending angle: 150° ± 5° or more.~~ The bending angle should be minimum 150°.

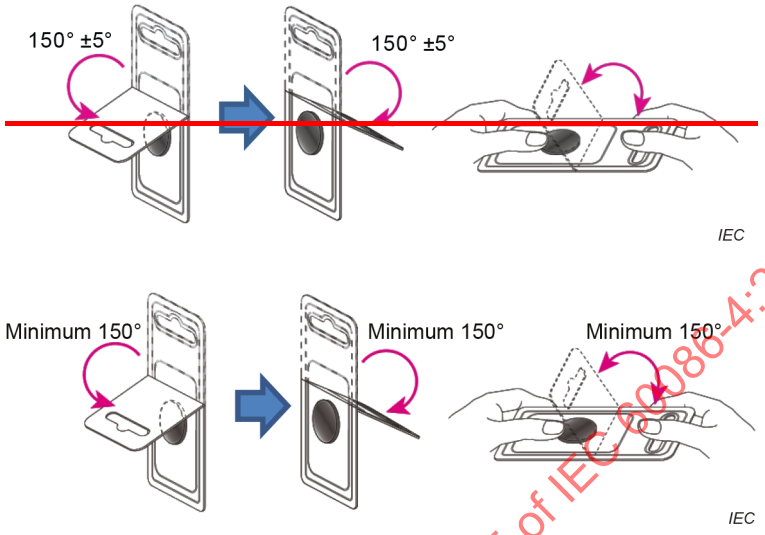


Figure E.1 – Bending test

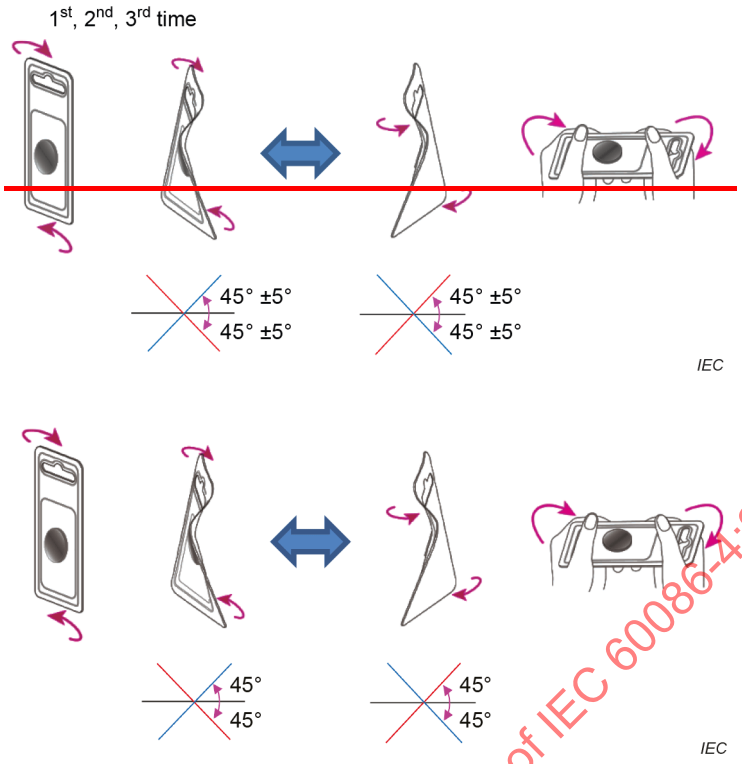
b) Torsion test

Hold the packaging with the fingers of one hand on each of its shorter sides and twist it diagonally with a torsion angle of 45° ±5° in opposite directions as shown in Figure E.2, three times in both directions:

Step 1 Hold the packaging with the fingers of one hand on each of its shorter sides from the state of 0 degrees (neutral state without torsion). Twist it diagonally with a torsion angle of 45° in opposite directions as shown in Figure E.2. 6

Step 2 Twist it diagonally 90° (45° back and 45° opposite direction) in opposite directions to the direction twisted at the first time.

Step 3 Return to neutral state without torsion (45° back).



NOTE The red and blue lines represent the top and bottom edge of the packaging.

Figure E.2 – Torsion test

c) Tearing test

Try to tear the cell compartment with the fingers as shown in Figure E.3. Alternatively use suitable equipment and apply a force of at least 25 N.

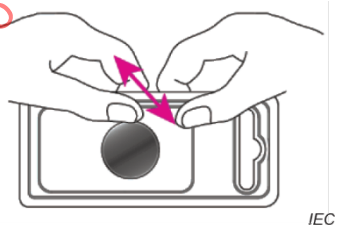


Figure E.3 – Tearing test

d) Pushing test

Try to push the cell out of the compartment with the fingers. Alternatively pull with a mass of at least 5 kg for 30 s; as shown in Figure E.4.

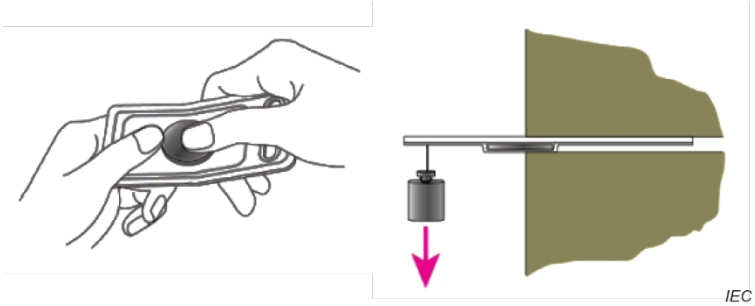


Figure E.4 – Pushing test

E.3.3 Test procedure

Sample ~~packagings~~ packages shall be tested in the condition of the packaging as sold to the consumer. The number of test samples shall be 10 ~~packagings~~ packages. Each sample shall be subjected to a series of tests in the order and frequence outlined in Table E.1.

Table E.1 – Test procedure

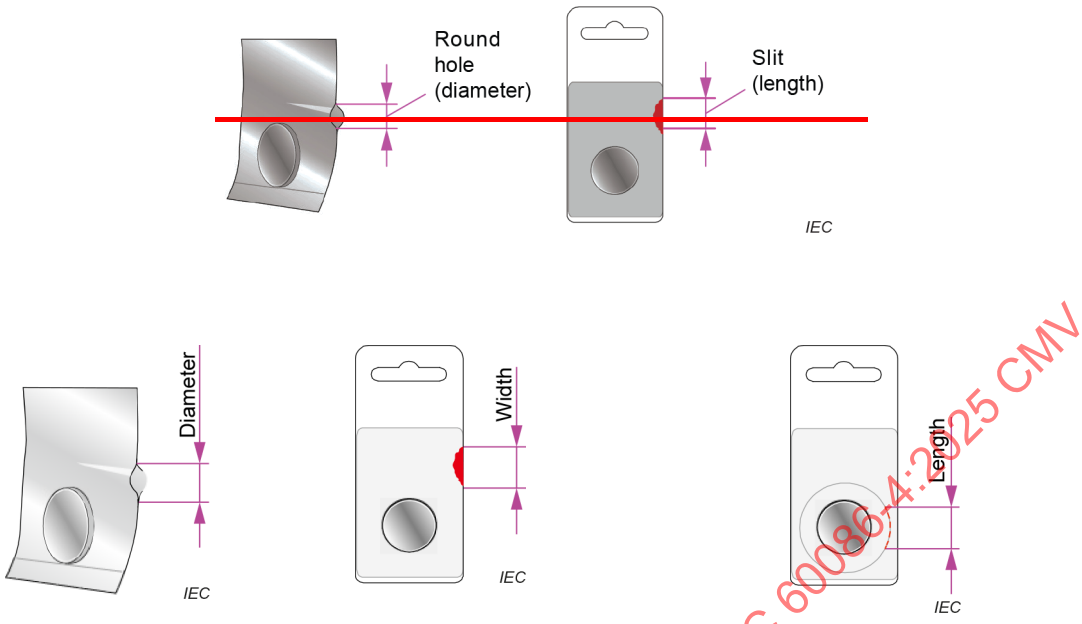
Order	Test item		Number of times
(1)	a)	Bending test	50
(2)	b)	Torsion test	25
(3)	c)	Tearing test	1
(4)	b)	Torsion test	25
(5)	a)	Bending test	50
(6)	c)	Tearing test	1
(7)	d)	Pushing test	1

E.3.4 Criteria

Each test sample shall meet the following criteria.

a) Each cell shall be kept in its packaging until the end of the test series, and

b) In order to prevent a child from pulling the cell out from its compartment, the packaging shall not open too wide. ~~The maximum allowable size of an opening in the packaging is 6 mm diameter for a round hole and 10 mm length for a slit. See Figure E.5 for maximum packaging openings.~~ The maximum allowable size of an opening in the packaging is 6 mm diameter for a round hole (see Figure E.5 a) for an example) and 10 mm width for a slit (see Figure E.5 b) for an example). If the perimeter of the cell itself is protected, the maximum allowable length of an arc-shaped opening in the primary protective seal around the cell is 10 mm (see Figure E.5 c) for an example). 7



a) Round hole b) Slit c) Arc in primary protective seal

Figure E.5 – Maximum packaging opening

Annex F
(~~informative~~normative) 8

Use of the KEEP OUT OF REACH OF CHILDREN safety sign

F.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its battery voltage ~~in excess of 2 V~~ causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

The ~~new~~ purpose of the safety sign KEEP OUT OF REACH OF CHILDREN ~~should~~ is to give parents who have children a heads-up as a mandatory action sign even if intended products are safe in the usual sense of adults.

Therefore, the purpose of the ~~new~~ safety sign is ~~used~~ to convey the message that these products ~~should~~ shall be kept out of reach of children in order to prevent accidental ingestion.

F.2 Safety sign

When a safety sign is used to convey the message that these products ~~should~~ shall be kept out of reach of children, the following ~~best practices apply~~ applies. The safety sign recommendation and cautionary advice for use on batteries and battery packaging are given in Table D.1, safety sign E, while warning text for safety information about battery handling is given in Figure 9.

F.3 ~~Best practices for~~ Marking on the packaging

a) Refer to ~~Table 9~~ Table 10 for marking requirements on packaging.

b) The safety sign ~~should~~ shall be on contrasting background. The background ~~should~~ shall cover at least 50 % of the area of the pictogram.

c) The size of the safety sign ~~should~~ shall be such that the diameter is 6 mm ~~in diameter~~ or larger.

d) If the text KEEP OUT OF REACH OF CHILDREN is used, it ~~should~~ shall contrast with the background color on which it is printed.

F.4 ~~Best practices for~~ Marking on the cell

a) Refer to ~~Table 9~~ Table 10 for marking requirements on coin cells.

b) The safety sign ~~should~~ shall be applied durably and indelibly ~~marked~~. No colour is required. Engraving, etching, embossing or stamping are acceptable.

c) The safety sign on cells ~~should~~ shall have a diameter of 6 mm or larger.

NOTE ~~Recommended~~ Alternative versions of the safety sign~~s~~ are shown in Figure F.1. The manufacturer can select any of ~~the safety signs~~ them.

a) Type 1 b) Type 2 c) Type 3

Figure F.1 – ~~Recommended~~ Safety signs for use on coin cells

Annex G
(normative)

Measures against misuse of batteries not intended for consumer replacement 9

G.1 Background

Lithium primary batteries are at risk of explosion or fire, if they are subjected to reverse (charging) current beyond the manufacturer's assumed current value (conditions deviating from Test I in 6.5.6).

Therefore, under any circumstances, lithium primary batteries must not be recharged.

However, with the advent of lithium secondary batteries and their chargers that are size-compatible with the lithium primary batteries standardised in IEC 60086-2, there is a risk that the lithium primary battery will be accidentally inserted into a battery charger.

In particular, lithium primary batteries not standardised in IEC 60086-2 are at risk of particularly serious accidents.

Batteries not standardised in IEC 60086-2 are generally not intended for consumer replacement[3] but are distributed only to equipment manufacturers and at most to specialist retailers and technically skilled consumers. They are generally rigidly soldered or permanently and unmistakeably connected to a circuit by means of a harness. Under no circumstances must they be inserted in battery compartments of equipment designed for battery replacement by the end consumer. This holds particularly for battery chargers.

Refer to 7.1.2 for safety measures which must be implemented when such batteries are incorporated into a circuit powered by an independent main power source.

The purpose of this annex is to identify such batteries and specify requirements for their marking, packaging, and placing on the market.

G.2 Additional measures for the prevention of confusion of primary batteries not intended for consumer replacement with secondary batteries

G.2.1 Identification of primary (non-rechargeable) batteries not intended for consumer replacement

Primary batteries are considered to present a particular risk when inserted in battery chargers if they have the following properties:

a) The battery belongs to voltage range 2 according to IEC 60086-1:2021, 4.1.7. This voltage range is characterized by a standard discharge voltage in the range from 2,72 V to 3,68 V; and

b) The battery is not specified in IEC 60086-2 but is dimensionally interchangeable with a battery type specified in IEC 60086-2; and

c) The battery meets one of the following conditions:

   i) The battery is not intended for consumer replaceable applications; or

   ii) The battery does not fulfil the design requirements of 4.1 c).

[3] Such batteries typically comply with the definition of industrial batteries in the European Batteries Regulation [28].

NOTE Batteries with harnesses or solder tags are not considered to be dimensionally interchangeable with their counterparts having no harnesses or solder tags.

G.2.2 Marking and information requirements for primary batteries not intended for consumer replacement

Primary batteries that have been identified according to G.2.1 as presenting a particular risk shall be placed on the market in such a way that they cannot end up in the reach of end users. They shall not be sold into applications where they can be replaced and inserted in equipment by the end user.

Where it cannot be prevented that such batteries end up in the reach of end users, the following additional measures shall be taken:

a) The batteries shall be packed individually in an immediate packaging, e.g. in a cardboard box or in a plastic bag; and

b) The batteries shall be marked visibly, legibly, and permanently according to the requirements of the local product safety legislation with an indication that they are not rechargeable and not intended for consumer replaceable applications; and

c) If this marking, due to lack of space, cannot be applied on the battery itself, the marking required in list item b) shall be confirmed on the immediate packaging; and

d) The indication according to list item b) shall also be applied in connection with offers for sale in such a way that it can easily be found and read. Offers for sale on the internet shall be set up in such a way that the buyer, before completing the purchase, has to confirm separately that he has read and understood the indication.

G.2.3 Information responsibility of manufacturers and distributors

Manufacturers and distributors of primary batteries that have been identified according to G.2.1 as presenting a particular risk shall inform their customers about the particular risk of these batteries and the requirements for their marking, e.g. by referring to Annex G of this document in the data sheets and in the shipping documents. Furthermore, they shall ensure in an appropriate manner that this information responsibility is passed on along the supply chain.

Bibliography

[1] IATA, International Air Transport Association, Quebec: *Dangerous Goods Regulations* (revised annually)

[2] ICAO, International Civil Aviation Organization, Montreal: *Technical Instructions for the Safe Transport of Dangerous Goods by Air* (revised biennially)

[3] IEC 60050-482:2004, *International Electrotechnical Vocabulary (IEV) – Part 482: Primary and secondary cells and batteries*

[4] IEC 60027-1:1992, *Letters symbols to be used in electrical technology – Part 1: General*

[5] IEC 60068-2-6:1995, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

[6] IEC 60068-2-27:1987, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

[7] IEC 60068-2-31:2008, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

[8] IEC 60086-5:~~2016~~2021, *Primary batteries – Part 5: Safety of batteries with aqueous electrolyte*

[9] IEC 60617 (all parts), *Graphical symbols for diagrams* (available at https://std.iec.ch/iec60617)

[10] IEC 62133-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary ~~lithium~~ cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems*

[11] IEC 61960 (all parts), *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

~~[12] IEC 62281, *Safety of primary and secondary lithium cells and batteries during transport*~~

[12] IMO, International Maritime Organization, London: *International Maritime Dangerous Goods (IMDG) Code* (revised biennially)

[13] ISO/IEC GUIDE 50~~:2002~~, *Safety aspects – Guidelines for child safety in standards and other specifications*

[14] ISO/IEC GUIDE 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

[15] ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

[16] ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

[17] ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*. Graphical symbols can be searched in the ISO Online Browsing Platform under https://www.iso.org/obp/ui/en/#search

[18] ISO 8124-1, *Safety of toys – Part 1: Safety aspects related to mechanical and physical properties*

[19] UL 1642, *Underwriters Laboratories, Standard for Lithium batteries*

[20] United Nations, New York and Geneva: *Recommendations on the Transport of Dangerous Goods, Model Regulations* (revised biennially)

[21] United Nations, New York and Geneva~~:2011~~, *Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Chapter 38.3* (revised biennially)

[22] Battery Association of Japan: *Guideline for the design and production of safe Lithium batteries for camera application, 2nd edition, March 1998*

[23] USA:16 CFR §1700.15(b)(1)

[24] EN 862, *Packaging. Child-resistant packaging. Requirements and testing procedures for non-reclosable packages for non-pharmaceutical products*

[25] AS 5808-2009, *Child-resistant packaging – Requirements and testing procedures for non-reclosable packages for non-pharmaceutical products*

[26] IEC 60417, *Graphical symbols for use on equipment*

[27] IEC 82079-1, *Preparation of information for use (instructions for use) of products – Part 1: Principles and general requirements*

[28] Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, Official Journal L 191, 28.7.2023 (*Batteries Regulation*)

List of comments

1 This change is related to item a) of the list of significant technical changes in the Foreword.

A definition for a term is different from a method for determining a value for the variable represented by that term. The method for determining whether a cell or battery is leaking or not is described in Subclause 6.2.3.

2 This change is related to item a) of the list of significant technical changes in the Foreword.

A definition for a term is different from a method for determining a value for the variable represented by that term. The method for determining whether a cell or battery has vented or not is described in Subclause 6.2.4.

3 These changes are related to item b) of the list of significant technical changes in the Foreword.

They are a consequence of adjusting the test method to the application of lithium primary batteries observed in the market.

4 The addition of this subclause acknowledges the fact that measures against inadvertent ingestion of coin cells become more important as the market penetration of this product type increases. It is also an attempt to increase the awareness of the different ingestion risks related coin and button cells because of their different sizes and voltage levels.

5 This change is related to item c) of the list of significant technical changes in the Foreword.

It constitutes the main change made in Clause 9 Marking: Extension of the requirement to have the KEEP OUT OF REACH OF CHILDREN safety sign on coin cells and batteries to those with a diameter between 16 mm and 20 mm. The other changes in Clause 9 are mainly due to an attempt to make the wording clearer and to harmonize it with IEC 60086-5.

6 This change is related to item g) of the list of significant technical changes in the Foreword.

The description of the test procedures is improved for easier comprehension.

7 This change is related to item d) of the list of significant technical changes in the Foreword.

Figure E.5 c) and a description of the related criterion are added because different packaging methods have different failure modes.

8 This change is related to item e) of the list of significant technical changes in the Foreword.

As prevention of inadvertent ingestion of coin cells becomes more important and in order to support the requirement for the safety sign to appear ON THE BATTERY in certain cases, this Annex is made normative.

9 This change is related to item f) of the list of significant technical changes in the Foreword.

It became necessary after a fatal accident had occurred in Hamburg in August 2018. A young man had replaced a rechargeable lithium ion battery with a non-rechargeable lithium primary battery of the E-system. The battery charger – although “intelligent” – did not recognize it and charged the battery until it exploded. As it is not possible to prevent such misuse with technical measures, organizational measures are described in this new Annex G. They address both distributors and manufacturers as well as other parties along the supply chain of this kind of batteries.

See the attached presentation for more information.

IEC 60086-4

Edition 6.0 2025-01

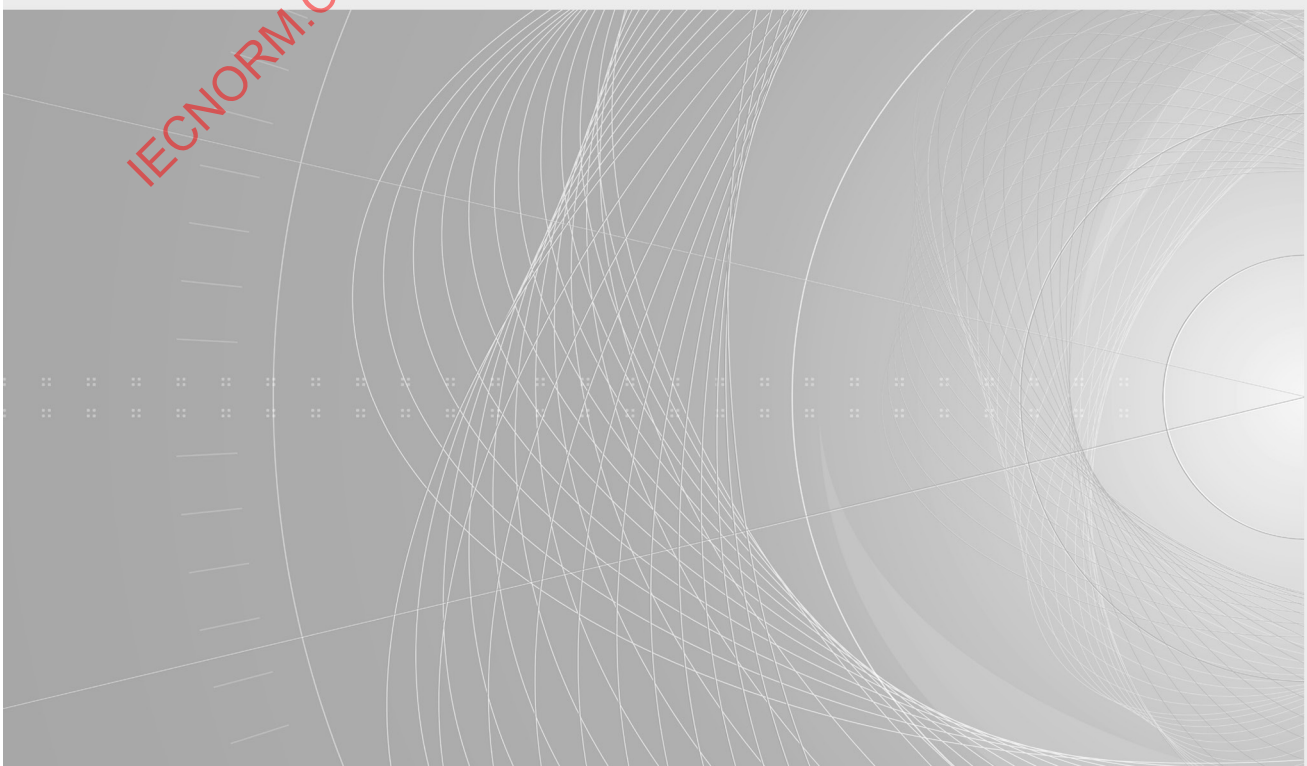
INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Primary batteries –
Part 4: Safety of lithium batteries

Piles électriques –
Partie 4: Sécurité des piles au lithium



IEC 60086-4:2025-01 (en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 60086-4 has been prepared by technical committee 35: Primary cells and batteries. It is an International Standard.

This sixth edition cancels and replaces the fifth edition published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Added definitions for leakage and venting, in addition to the test criteria;
b) Revised overdischarge test;
c) Revised marking requirements;
d) Revised criteria for the child resistant packaging test;
e) Changed the purpose of Annex F from "informative" to "normative";

f) Added a new Annex G with additional measures against misuse of batteries not intended for consumer replacement;

g) Integrated the contents of Interpretation Sheet 1 (IEC 60086-4:2019/ISH1:2020);

h) In Clause 3, terms were reordered according their functions: basic terms, electrochemical systems, battery shapes, battery sizes, electrical characteristics, specifications, safety aspects, failure modes;

i) In 6.4.4, the exemption for the shock acceleration for lithium primary batteries was reduced from 12 kg to 4,482 kg in order to reflect the fact that this is the threshold in IEC 62281, Test T-4, where the peak acceleration decreases below 150 g_n.

The text of this International Standard is based on the following documents:

Draft	Report on voting
35/1571/FDIS	35/1579/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

NOTE 1 The following print types are used:

– instructions/warnings for consumers: *in italic type*.

A list of all parts in the IEC 60086 series, under the general title *Primary batteries*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

NOTE 2 The attention of National Committees is drawn to the fact that equipment manufacturers and testing organizations may need a transitional period following publication of a new, amended or revised IEC document in which to make products in accordance with the new requirements and to equip themselves for conducting new or revised tests. It is the recommendation of the committee that the content of this document be adopted for implementation nationally not earlier than 2 years from the date of publication. The transitional period applies specifically to changes in Table 10. In the meantime, the previous edition can still be ordered by contacting your local IEC member National Committee or the IEC Secretariat.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The concept of safety is closely related to safeguarding the integrity of people and property. This document specifies tests and requirements for lithium batteries and has been prepared in accordance with ISO/IEC guidelines, taking into account all relevant national and international standards which apply.

Lithium batteries are different from conventional primary batteries using aqueous electrolyte in that they contain flammable materials.

Consequently, it is important to carefully consider safety during design, production, distribution, use, and disposal of lithium batteries. Based on such special characteristics, lithium batteries for consumer applications were initially small in size and had low power output. There were also lithium batteries with high power output which were used for special industrial and military applications and were characterized as being "technician replaceable". The first edition of this document was drafted to accommodate this situation.

However, from around the end of the 1980s, lithium batteries with high power output started to be widely used in the consumer replacement market, mainly as a power source in camera applications. Since the demand for such lithium batteries with high power output significantly increased, various manufacturers started to produce these types of lithium batteries. As a consequence of this situation, the safety aspects for lithium batteries with high power output were included in the second edition of this document.

Primary lithium batteries both for consumer and industrial applications are well-established safe and reliable products in the market, which is at least partly due to the existence of safety standards such as this document and, for transport, IEC 62281. The fourth edition of this document reflected minor changes which became necessary in order to keep it harmonized with IEC 62281 and to continuously improve the user information about safety related matters.

Guidelines addressing safety issues during the design of lithium batteries are provided in Annex A. Annex B provides guidelines addressing safety issues during the design of equipment where lithium batteries are installed. Both Annex A and Annex B reflect experience with lithium batteries used in camera applications and are based on [22][1].

The ingestion hazard of coin cell batteries has become an issue and was addressed in the fifth and sixth editions of this document by several independent measures such as the development of a new safety sign "KEEP OUT OF REACH OF CHILDREN" as well as the introduction of child resistant packaging.

A new Annex G addresses measures against misuse of cells and batteries not intended for consumer replacement.

Safety is freedom from unacceptable risk. There can be no absolute safety: some risk will remain. Therefore a product, process or service can only be relatively safe. Safety is achieved by reducing risk to a tolerable level determined by the search for an optimal balance between the ideal of absolute safety and the demands to be met by a product, process or service, and factors such as benefit to the user, suitability for purpose, cost effectiveness, and conventions of the society concerned.

As safety will pose different problems, it is impossible to provide a set of precise provisions and recommendations that will apply in every case. However, this document, when followed on a judicious "use when applicable" basis, will provide reasonably consistent standards for safety.

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1 Numbers in square brackets refer to the Bibliography.

PRIMARY BATTERIES –

Part 4: Safety of lithium batteries

1 Scope

This part of IEC 60086 specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.

NOTE Primary lithium batteries that are standardized in IEC 60086-2 are expected to meet all applicable requirements herein. It is understood that consideration of this part of IEC 60086 might also be given to measuring and/or ensuring the safety of non-standardized primary lithium batteries. In either case, no claim or warranty is made that compliance or non-compliance with this part of IEC 60086 will fulfil or not fulfil any of the user's particular purposes or needs.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60086-1:2021, *Primary batteries – Part 1: General*

IEC 60086-2, *Primary batteries – Part 2: Physical and electrical specifications*

IEC 62281, *Safety of primary and secondary lithium cells and batteries during transport*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

NOTE Certain definitions taken from IEC 60050-482, IEC 60086-1, and ISO/IEC Guide 51 are repeated below for convenience.

3.1
cell
basic functional unit, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy

[SOURCE: IEC 60050-482:2004, 482-01-01]

3.2
battery
one or more cells electrically connected and fitted in a case, with terminals, markings and protective devices etc., as necessary for use

[SOURCE: IEC 60050-482:2004, 482-01-04, modified – "fitted with devices necessary for use, for example case" replaced by "electrically connected and fitted in a case", addition of "etc., as necessary for use".]

3.3
component cell
cell contained in a battery

3.4
lithium cell
cell containing a non-aqueous electrolyte and a negative electrode of lithium or containing lithium

[SOURCE: IEC 60050-482:2004 482-01-06, modified – removal of Note.]

3.5
coin cell
coin battery
lithium button cell
lithium button battery
small round cell or battery where the overall height is less than the diameter, containing non-aqueous electrolyte.

Note 1 to entry: The nominal voltage of lithium batteries is typically greater than 2 V. See also the definition of "button cell" in IEC 60086-5

Note 2 to entry: See 7.3 for proposed use of the alternative terms.

Note 3 to entry: The terms "lithium button cell" and "lithium button battery" were provided as alternative terms for "coin cell" and "coin battery" in order to prevent the use of the terms "button cell" and "button battery" which would be confusing as they have a different meaning, see part 1 of this standard.

Consequently, the terms "coin cell" and "coin battery" should be omitted in those languages where they have no meaningful literal equivalent.

[SOURCE: IEC 60050-482:2004 482-02-40, modified – terms modified, Note replaced.]

3.6
cylindrical cell
cylindrical battery
round cell or battery in which the overall height is equal to or greater than the diameter

[SOURCE: IEC 60050-482:2004, 482-02-39, modified – "cell with a cylindrical shape" replaced by "round cell or battery".]

3.7
prismatic cell
prismatic battery
cell or battery having the shape of a parallelepiped whose faces are rectangular

[SOURCE: IEC 60050-482:2004, 482-02-38]

3.8
large cell
cell with a gross mass of more than 500 g

3.9
large battery
battery with a gross mass of more than 12 kg

3.10
nominal voltage
suitable approximate value of the voltage used to designate or identify a cell, a battery or an electrochemical system

[SOURCE: IEC 60050-482:2004, 482-03-31]

3.11
open circuit voltage
OCV, U_{OC}, off-load voltage
voltage across the terminals of a cell or battery when no external current is flowing

[SOURCE: IEC 60050-482:2004, 482-03-32, modified – alternative terms "OCV, U_{OC}, off-load voltage" added, "across the terminals" added, "when the discharge current is zero" replaced with "when no external current is flowing".]

3.12
rated capacity
capacity value of a cell or battery determined under specified conditions and declared by the manufacturer

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – "cell or" added.]

3.13
depth of discharge
DOD
percentage of rated capacity discharged from a cell or battery

3.14
undischarged
state of a primary cell or battery at 0 % depth of discharge

3.15
fully discharged
state of a cell or battery at 100 % depth of discharge

3.16
harm
injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.17
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.18
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified – removal of Note.]

3.19
safety
freedom from risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.20
intended use
use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

[SOURCE: ISO/IEC Guide 51:2014, 3.6]

3.21
reasonably foreseeable misuse
use of a product, process or system in a way not intended by the supplier, but which may result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – removal of Notes.]

3.22
protective devices
devices such as fuses, diodes or other electric or electronic current limiters designed to interrupt the current flow, block the current flow in one direction or limit the current flow in an electrical circuit

3.23
leakage
unplanned escape of electrolyte, gas or other material from a cell or battery

Note 1 to entry: Leakage in this sense should not be confused with the test evaluation criteria for leakage specified in Clause 6.

3.24
venting
release of excessive internal pressure from a cell or battery in a manner intended by design

Note 1 to entry: Venting in this sense should not be confused with the test evaluation criteria for venting specified in Clause 6.

4 Requirements for safety

4.1 Design

Lithium batteries are categorized by their chemical composition (anode, cathode, electrolyte), internal construction (bobbin, spiral) and are available in cylindrical, coin and prismatic configurations. It is necessary to consider all relevant safety aspects at the battery design stage, recognizing the fact that they can differ considerably, depending on the specific lithium system, power capability and battery configuration.

The following design concepts for safety are common to all lithium batteries:

a) Abnormal temperature rise above the critical value defined by the manufacturer shall be prevented by design.

b) Temperature increases in the battery shall be controlled by a design which limits current flow.

c) Lithium cells and batteries shall be designed to relieve excessive internal pressure or to preclude a violent rupture under conditions of transport, intended use and reasonably foreseeable misuse.

If, in particular cases, this design concept cannot be implemented, the organisational requirements described in Annex G shall apply.

See Annex A for guidelines for the achievement of safety of lithium batteries.

4.2 Quality plan

The manufacturer shall prepare and implement a quality plan defining the procedures for the inspection of materials, components, cells and batteries during the course of manufacture, to be applied to the total process of producing a specific type of battery. Manufacturers should understand their process capabilities and should institute the necessary process controls as they relate to product safety.

5 Type testing and sampling

5.1 Validity of testing

Lithium cells or batteries shall be subjected to the tests, as required in this document. Testing remains valid until a design change or requirement revision has been made. Retesting is required when:

a) a battery specification changes by more than 0,1 g or 20 % mass, whichever is greater, for the cathode, anode or electrolyte;

b) a battery specification change would lead to a failure of any of the tests;

c) there is an addition of new tests or requirements; or

d) there is a requirement change that would lead to a failure of any of the tests.

5.2 Test samples

Samples should be drawn from production lots in accordance with accepted statistical methods. The number of test samples is given in Table 1. The same test cells and batteries are used for tests A to E in sequence. New test cells and batteries are required for each of tests F to M.

Table 1 – Number of test samples

Tests	Discharge state		Cells or single cell batteries[a]	Multi-cell batteries
Tests A to E	Undischarged		10	4
	Fully discharged		10	4
Test F or G	Undischarged		5	5 component cells
	Fully discharged		5	5 component cells
Test H	Fully discharged		10	10 component cells
Tests I to K	Undischarged		5	5
Test L	Undischarged		20[b]	n/a
Test M	50 % predischarged	CR	10[c]	n/a
	Fully discharged	CR	10[d]	n/a
	50 % predischarged	FR	20[e]	n/a
	Fully discharged	FR	20[f]	n/a

Key

n/a: not applicable

[a] Single cell batteries containing one tested component cell do not require re-testing unless the change could result in a failure of any of the tests.

[b] Four batteries connected in series with one of the four batteries reversed (5 sets).

[c] Two CR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.

[d] Two CR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.

[e] Four FR-type batteries connected in series, one of which is 50 % predischarged (5 sets). Undischarged cells shall be sampled from the same production lot.

[f] Four FR-type batteries connected in series, one of which is fully discharged (5 sets). Undischarged cells shall be sampled from the same production lot.

6 Testing and requirements

6.1 General

6.1.1 Test application matrix

Applicability of test methods to test cells and batteries is shown in Table 2.

Table 2 – Test application matrix

Form	Applicable tests												
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	x	x	x	x	x	x [a]	x [a]	x	x	x	x	x [b]	x [c]
m	x	x	x	x	x	x [a, d]	x [a, d]	x [d]	x	x	x	n/a	n/a

Test description:		Key:	
Intended use tests A: Altitude B: Thermal cycling C: Vibration D: Shock	Reasonably foreseeable misuse tests E: External short-circuit F: Impact G: Crush H: Forced discharge I: Abnormal charging J: Free fall K: Thermal abuse L: Incorrect installation M: Overdischarge	Form s: cell or single cell battery m: multi cell battery Applicability x: applicable n/a: not applicable	

[a] Only one test shall be applied, test F or test G.

[b] Only applicable to CR17345, CR15H270, FR14505, FR10G445 and similar type batteries of a spiral construction that could be installed incorrectly and charged.

[c] Only applicable to CR17345, CR15H270, FR14505, FR10G445 and similar type batteries of a spiral construction that could be overdischarged.

[d] Test applies to the component cells.

6.1.2 Cautionary notice

WARNING: These tests call for the use of procedures which can result in injury if adequate precautions are not taken.

It has been assumed in the drafting of these tests that their execution is undertaken by appropriately qualified and experienced technicians using adequate protection.

6.1.3 Ambient temperature

Unless otherwise specified, the tests shall be carried out at an ambient temperature of 20 °C ± 5 °C.

6.1.4 Parameter measurement tolerances

The overall accuracy of controlled or measured values, relative to the specified or actual parameters, shall be within the following tolerances:

a) ± 1 % for voltage;

b) ± 1 % for current;

c) ± 2 °C for temperature;

d) ± 0,1 % for time;

e) ± 1 % for dimensions;

f) ± 1 % for capacity.

These tolerances comprise the combined accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

6.1.5 Predischarge

Where a test requires predischarge, the test cells or batteries shall be discharged to the respective depth of discharge on a resistive load with which the rated capacity is obtained or at a current specified by the manufacturer.

6.1.6 Additional cells

Where additional cells are required to perform a test, they shall be of the same type and, preferably, from the same production lot as the test cell.

6.2 Evaluation of test criteria

6.2.1 Short-circuit

A short-circuit is considered to have occurred during a test if the open circuit voltage of the cell or battery immediately after the test is less than 90 % of its voltage prior to the test. This requirement is not applicable to test cells and batteries in fully discharged states.

6.2.2 Excessive temperature rise

An excessive temperature rise is considered to have occurred during a test if the external case temperature of the test cell or battery rises above 170 °C.

6.2.3 Leakage

Leakage is considered to have occurred during a test if there is visible escape of electrolyte or other material from the test cell or battery, or the loss of material (except battery casing, handling devices or labels) from the test cell or battery such that the mass loss exceeds the limits in Table 3.

In order to quantify mass loss $\Delta m / m$, the following equation is provided:

$$\Delta m / m = \frac{m_1 - m_2}{m_1} \times 100\ \%$$

where

m_1 is the mass before a test;

m_2 is the mass after that test.

Table 3 – Mass loss limits

Mass of cell or battery m	Mass loss limit $\Delta m / m$
m < 1 g	0,5 %
1 g ≤ m ≤ 75 g	0,2 %
m > 75 g	0,1 %

6.2.4 Venting

Venting is considered to have occurred if, during a test, an excessive build up of internal gas pressure escapes from a cell or battery through a pressure relief feature designed for this purpose. This gas may include entrapped materials.

6.2.5 Fire

A fire is considered to have occurred if, during a test, flames are emitted from the test cell or battery.

6.2.6 Rupture

A rupture is considered to have occurred if a cell container or battery case has mechanically failed, resulting in expulsion of gas or spillage of liquids but not forcible ejection of solid materials.

6.2.7 Explosion

An explosion is considered to have occurred if a cell container or battery case opens violently and solid components are forcibly ejected. During cell or component cell testing, ejection of internal components is acceptable. Energy of ejected components shall be limited. If required, it may be measured as follows:

a) It will not penetrate a wire mesh screen (annealed aluminium wire with a diameter of 0,25 mm and grid density of 6 to 7 wires per cm) placed 25 cm away from the cell; or

b) It can be measured by a method demonstrated to be equivalent to the one described in a).

6.3 Tests and requirements – Overview

This document provides safety tests for intended use (tests A to D) and reasonably foreseeable misuse (tests E to M). Table 4 contains an overview of the tests and requirements for intended use and reasonably foreseeable misuse.

Table 4 – Tests and requirements

Test number		Designation	Requirements
Intended use tests	A	Altitude	NL, NV, NC, NR, NE, NF
	B	Thermal cycling	NL, NV, NC, NR, NE, NF
	C	Vibration	NL, NV, NC, NR, NE, NF
	D	Shock	NL, NV, NC, NR, NE, NF
Reasonably foreseeable misuse tests	E	External short-circuit	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Crush	NT, NE, NF
	H	Forced discharge	NE, NF
	I	Abnormal charging	NE, NF
	J	Free fall	NV, NE, NF
	K	Thermal abuse	NE, NF
	L	Incorrect installation	NE, NF
	M	Overdischarge	NE, NF

Tests A through E shall be conducted in sequence on the same cell or battery.
Tests F and G are provided as alternatives. Only one of them shall be conducted.

Key

NC: No short-circuit
NE: No explosion
NF: No fire
NL: No leakage
NR: No rupture
NT: No excessive temperature rise
NV: No venting

See 6.2 for a detailed description of the test criteria.

6.4 Tests for intended use

6.4.1 Test A: Altitude

a) Purpose

This test simulates air transport under low pressure conditions.

b) Test procedure

Test cells and batteries shall be stored at a pressure of 11,6 kPa or less for at least 6 h at ambient temperature.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.2 Test B: Thermal cycling

a) Purpose

This test assesses cell and battery seal integrity and that of their internal electrical connections. The test is conducted using temperature cycling.

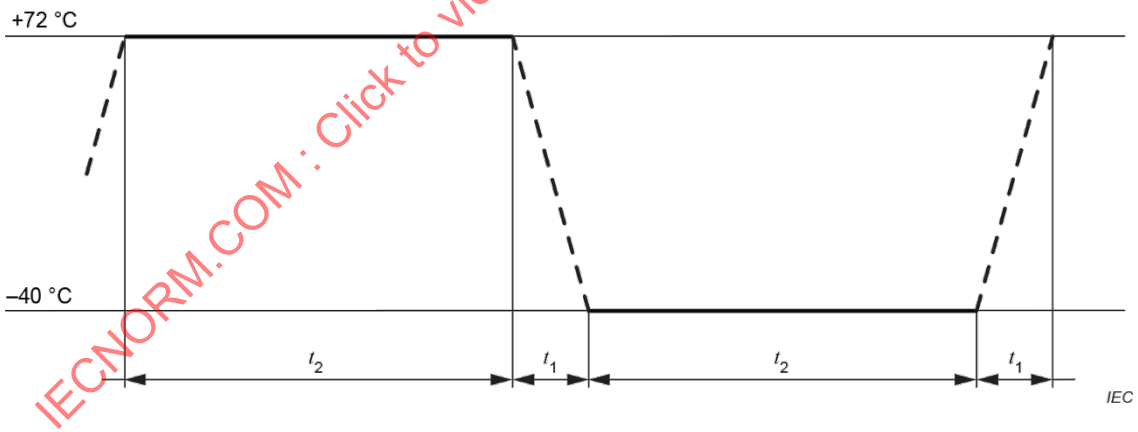
b) Test procedure

Test cells and batteries shall be stored for at least 6 h at a test temperature of 72 °C, followed by storage for at least 6 h at a test temperature of –40 °C. The maximum time for transfer to each temperature shall be 30 min. Each test cell and battery shall undergo this procedure 10 times. This is then followed by storage for at least 24 h at ambient temperature.

For large cells and batteries the duration of exposure to the test temperatures shall be at least 12 h instead of 6 h.

Figure 1 shows a diagram of one of ten thermal cycles.

The test shall be conducted using the test cells and batteries previously subjected to the altitude test.



Key

t_1 ≤ 30 min

t_2 ≥ 6 h (12 h for large cells and batteries)

Figure 1 – Thermal cycling procedure

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.3 Test C: Vibration

a) Purpose

This test simulates vibration during transport. The test condition is based on the range of vibrations as given by ICAO [2].

b) Test procedure

Test cells and batteries shall be firmly secured to the platform of the vibration machine without distorting them and in such a manner as to faithfully transmit the vibration. Test cells and batteries shall be subjected to sinusoidal vibration according to Table 5 which shows a different upper acceleration amplitude for large batteries. This cycle shall be repeated 12 times for a total of 3 h for each of three mutually perpendicular mounting positions. One of the directions shall be perpendicular to the terminal face.

The test shall be conducted using the test cells and batteries previously subjected to the thermal cycling test.

Table 5 – Vibration profile (sinusoidal)

Frequency range		Amplitudes	Duration of logarithmic sweep cycle (7 Hz – 200 Hz – 7 Hz)	Axis	Number of cycles
From	To				
f_1 = 7 Hz	f_2	a_1 = 1 g_n	15 min	X	12
f_2	f_3	s = 0,8 mm		Y	12
f_3	f_4 = 200 Hz	a_2		Z	12
and back to f_1 = 7 Hz				Total	36

Key

f_1, f_4 lower and upper frequency

f_2, f_3 cross-over frequencies;

f_2 ≈ 17,62 Hz; and

f_3 ≈ 49,84 Hz, except for large batteries, where f_3 ≈ 24,92 Hz

a_1, a_2 acceleration amplitude; a_2 = 8 g_n, except for large batteries, where a_2 = 2 g_n

s displacement amplitude

NOTE 1 Vibration amplitude is the maximum absolute value of displacement or acceleration. For example, a displacement amplitude of 0,8 mm corresponds to a peak-to-peak displacement of 1,6 mm.

NOTE 2 g_n = 9,806 65 m / s^2

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.4.4 Test D: Shock

a) Purpose

This test simulates rough handling during transport.

b) Test procedure

Test cells and batteries shall be secured to the testing machine by means of a rigid mount which will support all mounting surfaces of each test cell or battery. Each test cell or battery shall be subjected to 3 shocks in each direction of three mutually perpendicular mounting positions of the cell or battery for a total of 18 shocks. For each shock, the parameters given in Table 6 shall be applied.

Table 6 – Shock parameters

	Waveform	Peak acceleration	Pulse duration	Number of shocks per half axis
Cells or batteries except large ones	Half sine	150 g_n	6 ms	3
Large cells or batteries	Half sine	50 g_n	11 ms	3
NOTE g_n = 9,806 65 m / s^2				

For lithium primary batteries with a mass of more than 4,482 kg, the test method of test T-4 in IEC 62281 may be used.

The test shall be conducted using the test cells and batteries previously subjected to the vibration test.

c) Requirements

There shall be no leakage, no venting, no short-circuit, no rupture, no explosion and no fire during this test.

6.5 Tests for reasonably foreseeable misuse

6.5.1 General

The test methods described hereafter were developed for batteries specified in IEC 60086-2. However, they shall also be applied to batteries which are not specified therein. For batteries not specified in IEC 60086-2, additional requirements apply which are described in Annex G.

6.5.2 Test E: External short-circuit

a) Purpose

This test simulates conditions resulting in an external short-circuit.

b) Test procedure

The test cell or battery shall be stabilized at an external case temperature of 55 °C and then subjected to a short-circuit condition with a total external resistance of less than 0,1 Ω at 55 °C. This short-circuit condition is continued for at least 1 h after the cell or battery external case temperature has returned to 55 °C.

For lithium primary batteries with a mass in excess of 12 kg, the test method of test T-5 in IEC 62281 may be used.

The test sample shall be observed for a further 6 h.

The test shall be conducted using the test samples previously subjected to the shock test.

c) Requirements

There shall be no excessive temperature rise, no rupture, no explosion and no fire during this test and within the 6 h of observation.

6.5.3 Test F: Impact

a) Purpose

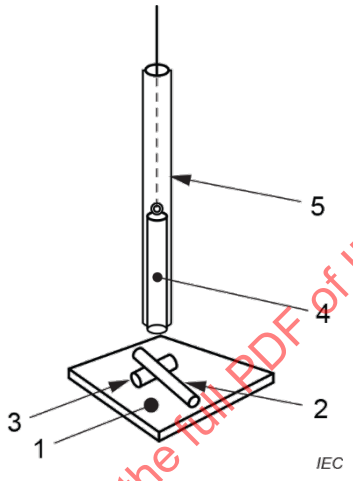
This test simulates mechanical abuse from an impact that can result in an internal short circuit.

b) Test procedure

The impact test is applicable to cylindrical cells not less than 18 mm in diameter.

The test cell or component cell is placed on a flat smooth surface. A stainless steel bar (type 316 or equivalent) with a diameter of 15,8 mm ± 0,1 mm and a length of at least 60 mm or of the longest dimension of the cell, whichever is greater, is placed across the centre of the test sample. A mass of 9,1 kg ± 0,1 kg is dropped from a height of 61 cm ± 2,5 cm at the intersection of the bar and the test sample in a controlled manner using a near frictionless, vertical sliding track or channel with minimal drag on the falling mass. The vertical track or channel used to guide the falling mass shall be oriented 90 degrees from the horizontal supporting surface.

The test sample is to be impacted with its longitudinal axis parallel to the flat surface and perpendicular to the longitudinal axis of the stainless steel bar lying across the centre of the test sample (see Figure 2).



NOTE The figure shows a flat smooth surface (1) and a stainless steel bar (2) which is placed across the centre of the test sample (3). A mass (4) is dropped at the intersection in a controlled manner using a vertical sliding channel (5).

Figure 2 – Example of a test set-up for the impact test

Each test cell or component cell shall be subjected to one impact only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test cells or component cells that have not been previously subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.4 Test G: Crush

a) Purpose

This test simulates mechanical abuse from a crush that can result in an internal short circuit.

b) Test procedure

The crush test is applicable to prismatic, flexible[2], coin cells and cylindrical cells less than 18 mm in diameter.

A cell or component cell is to be crushed between two flat surfaces. The crushing is to be gradual with a speed of approximately 1,5 cm/s at the first point of contact. The crushing is to be continued until one of the three conditions below is reached:

[2] The term “flexible cell” is used in this document in place of the term “pouch cell” which is used in [21]. It is also used in place of the terms “cell with a laminate film case” and “laminate film cell”.

1) The applied force reaches 13 kN ± 0,78 kN;

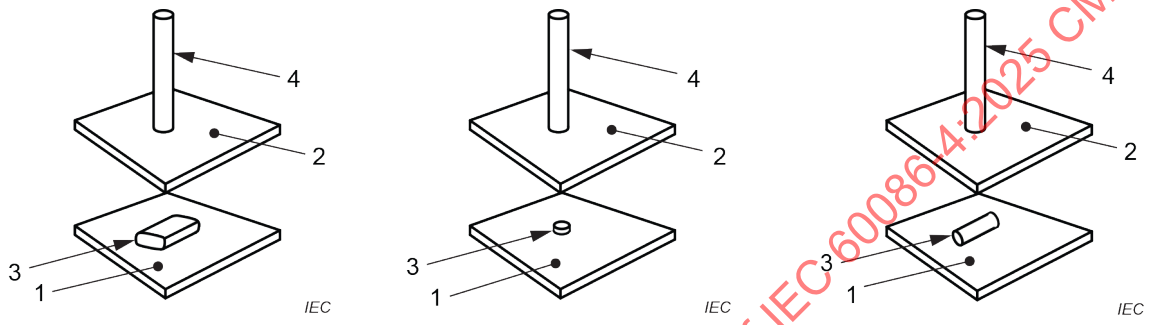
EXAMPLE: The force can be applied by a hydraulic ram with a 32 mm diameter piston until a pressure of 17 MPa is reached on the hydraulic ram.

2) The voltage of the cell drops by at least 100 mV; or

3) The cell is deformed by 50 % or more of its original thickness.

As soon as one of the above conditions has been obtained, the pressure shall be released.

A prismatic or flexible cell shall be crushed by applying the force to the side with the largest surface area. A coin cell shall be crushed by applying the force on its flat surfaces. For cylindrical cells, the crush force shall be applied perpendicular to the longitudinal axis. See Figure 3.



a) Prismatic or flexible cell **b) Coin cell** **c) Cylindrical cell**

NOTE The figures show two flat surfaces (1 and 2) with batteries (3) of different shapes placed between them for crushing, using a piston (4).

Figure 3 – Examples of a test set-up for the crush test

Each test cell or component cell is to be subjected to one crush only.

The test sample shall be observed for a further 6 h.

The test shall be conducted using test cells or component cells that have not previously been subjected to other tests.

c) Requirements

There shall be no excessive temperature rise, no explosion and no fire during this test and within the 6 h of observation.

6.5.5 Test H: Forced discharge

a) Purpose

This test evaluates the ability of a cell to withstand a forced discharge condition.

b) Test procedure

Each cell shall be force discharged at ambient temperature by connecting it in series with a 12 V direct current power supply at an initial current equal to the maximum continuous discharge current specified by the manufacturer.

The specified discharge current is obtained by connecting a resistive load of appropriate size and rating in series with the test cell and the direct current power supply. Each cell shall be force discharged for a time interval equal to its rated capacity divided by the initial test current.

This test shall be conducted with fully discharged test cells or component cells that have not previously been subjected to other tests.

c) Requirements

There shall be no explosion and no fire during this test and within 7 days after the test.

6.5.6 Test I: Abnormal charging

a) Purpose

This test simulates the condition when a battery is fitted within a device and is exposed to a reverse (charging) current from an external power supply, for example memory back-up equipment with a defective diode (see 7.1.2). The test condition is based upon UL 1642 [19].

NOTE This test does not take into account the case where a battery is misused by inserting it into a battery charger (inadvertent confusion with a rechargeable battery).

b) Test procedure

Each test battery shall be subjected to a charging current of three times the abnormal charging current I_c specified by the battery manufacturer by connecting it in opposition to a DC power supply. Unless the power supply allows for setting the current, the specified charging current shall be obtained by connecting a resistor of the appropriate size and rating in series with the battery.

The test duration shall be calculated using the formula:

$$t_d = 2{,}5 \times C_n / (3 \times I_c)$$

where

t_d is the test duration. In order to expedite the test, it is permitted to adjust the test parameters such that t_d does not exceed 7 days;

C_n is the nominal capacity declared by the manufacturer;

I_c is the abnormal charging current declared by the manufacturer for this test.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.7 Test J: Free fall

a) Purpose

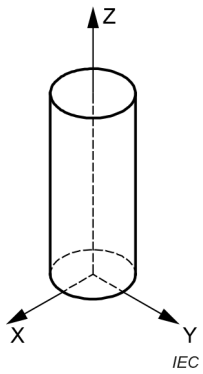
This test simulates the situation when a battery is accidentally dropped. The test condition is based upon IEC 60068-2-31 [7].

b) Test procedure

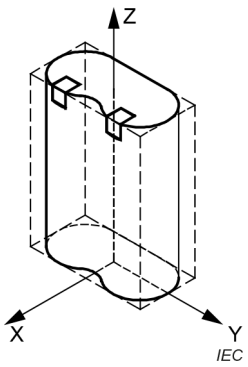
The test batteries shall be dropped from a height of 1 m onto a concrete surface. Each test battery shall be dropped six times, a prismatic battery once from each of its six faces, a round battery twice in each of the three axes shown in Figure 4a). The test batteries shall be stored for 1 h afterwards.

NOTE The term "prismatic" is used assuming that the battery shape can be fitted to a rectangular parallelepiped as shown in Figure 4b).

The test shall be conducted with undischarged test cells and batteries.



a) **Round cell or battery**



b) **Prismatic cell or battery**

Figure 4 – Axes for free fall

c) Requirements

There shall be no venting, no explosion and no fire during this test and within the 1 h of observation.

6.5.8 Test K: Thermal abuse

a) Purpose

This test simulates the condition when a battery is exposed to an extremely high temperature.

b) Test procedure

A test battery shall be placed in an oven and the temperature raised at a rate of 5 °C/min to a temperature of 130 °C at which the battery shall remain for 10 min.

c) Requirements

There shall be no explosion and no fire during this test.

6.5.9 Test L: Incorrect installation

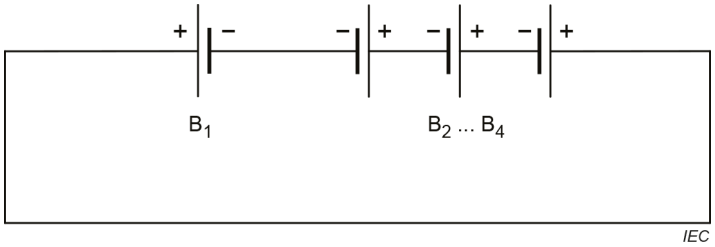
a) Purpose

This test simulates the condition when one single cell battery in a set is reversed.

NOTE Primary batteries are not designed to be charged. However, reversed installation of a battery in a series of three or more, as well as insertion into a battery charger, exposes the battery to a charging condition. Although cylindrical batteries are designed to relieve excessive internal pressure, in some instances an explosion might not be precluded.

b) Test procedure

A test battery is connected in series with three undischarged additional single cell batteries of the same brand and type in such a way that the terminals of the test battery are connected in reverse. The resistance of the interconnecting circuit shall be no greater than 0,1 Ω. The circuit shall be completed for 24 h or until the battery case temperature has returned to ambient (see Figure 5).



Key

B_1 Test cell

$B_2 ... B_4$ Additional cells, undischarged

Figure 5 – Circuit diagram for incorrect installation

c) Requirements

There shall be no explosion and no fire during this test.

6.5.10 Test M: Overdischarge

a) Purpose

This test simulates the condition when one discharged single cell battery is connected in series with other undischarged single cell batteries. The test further simulates the use of batteries in motor powered appliances or high intensity lighting applications where, in general, currents up to 1 A are required.

NOTE CR17345, CR15H270, FR14505 and FR10G445 batteries are widely used in motor powered appliances or high intensity lighting applications where currents up to 1 A are required. The current for non standardized batteries might be different.

b) Test procedure

Each test battery shall be predischarged to 50 % depth of discharge. A CR-type battery shall then be connected in series with one undischarged additional single cell battery of the same type. An FR-type battery shall be connected in series with three undischarged additional single cell batteries of the same type.

A resistive load R is connected in series with the assembly of n batteries in Figure 6 where R and n are taken from Table 7.

The test shall be continued for 24 h or until the battery case temperature has returned to ambient.

The test shall be repeated with fully discharged test batteries.

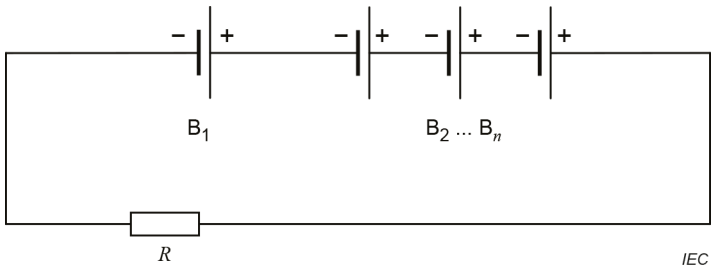
Table 7 – Resistive load for overdischarge

Battery type	Total number of single cell batteries in the assembly n	End-point voltage V	Resistive load R Ω
CR17345	2	1,8	3,60
CR15H270			
FR14505	4	0,9	
FR10G445			

NOTE Table to be modified or expanded when additional batteries of a spiral construction are standardized.

EXAMPLE The resistive load R for CR17345 and CR15H270 batteries was determined from the end-point voltage of each cell under the high intensity lighting test and the total number of cells in the test assembly in Figure 6 using the formula

$$R = 2 \times 1{,}8\ \text{V} / 1\ \text{A}$$



Key

B_1 Test battery, 50 % predischarged and, in separate tests, fully discharged

B_2... B_n Additional batteries, undischarged. The number of additional batteries is n-1

R Resistive load

Figure 6 – Circuit diagram for overdischarge

c) Requirements

There shall be no explosion and no fire during this test.

6.6 Information to be given in the relevant specification

When this document is referred to in a relevant specification, the parameters given in Table 8 shall be given in so far as they are applicable:

Table 8 – Parameters to be specified

Item	Parameters	Subclause
a)	Predischarge current or resistive load and end-point voltage specified by the manufacturer	6.1.5
b)	Method to measure the energy of an explosion, if any.	6.2.7
c)	Shape: prismatic, flexible, coin or cylindrical; Diameter: less than 18 mm or not less than 18 mm.	6.5.3 and 6.5.4
d)	Maximum continuous discharge current specified by the manufacturer for test H NOTE 1 Forced discharge of a cell can occur when it is connected in series with other cells and when it is not protected with a bypass diode.	6.5.5
e)	Rated capacity specified by the manufacturer for test H	6.5.5
f)	Abnormal charging current declared by the manufacturer for test I NOTE 2 Abnormal charging of a cell can occur when it is connected in series with other cells and one cell is reversed or when it is connected in parallel with a power supply and the protective devices do not operate correctly.	6.5.6
g)	Nominal capacity specified by the manufacturer	6.5.6
h)	Normal reverse current declared by the manufacturer which can be applied to the battery during its operating life NOTE 3 Normal reverse current flow through a cell can occur when it is connected in parallel with a power supply and the protective devices are operating properly.	7.1.2

6.7 Evaluation and report

When a report is issued, the following list of items should be considered:

a) name and address of the test facility;

b) name and address of applicant (where appropriate);

c) a unique test report identification;

d) the date of the test report;

e) design characteristics of the test cells or batteries according to 4.1;

f) test descriptions and results, including the parameters according to 6.6;

g) type of the test sample(s): cell, component cell, battery or battery assembly;

h) weight of the test sample(s);

i) lithium content of the sample(s);

j) a signature with name and status of the signatory.

It is not necessary to issue a new report unless new type testing is required, see 5.1.

7 Information for safety

7.1 Safety precautions during design of equipment

7.1.1 General

See also Annex B for guidelines for designers of equipment using lithium batteries.

7.1.2 Charge protection

When incorporating a primary lithium battery into a circuit powered by an independent main power source, protective devices shall be used in order to prevent charging the primary battery from the main power source, for example:

a) a blocking diode and a current limiting resistor (see Figure 7a);

b) two series blocking diodes (see Figure 7b);

c) circuits with a similar blocking function based on two or more independent protective devices;

provided that the first protective device is capable of limiting the charging current through the lithium battery to the normal reverse current specified by the manufacturer which can be applied to the battery during its operating life, while the second protective device is capable of limiting the charging current to the abnormal charging current specified by the battery manufacturer and used for conduction of test J, Abnormal charging. The circuit shall be so designed that at least one of these protective devices remains operational when any one component of the circuit fails.

a) Diode and resistor **b) Two diodes**

Figure 7 – Examples of wiring for charge protection

7.1.3 Parallel connection

Parallel connection should be avoided when designing battery compartments. However, if required, the battery manufacturer shall be contacted for advice.

7.2 Precautions during handling of batteries

When used correctly, lithium batteries provide a safe and dependable source of power. However, if they are misused or abused, leakage, venting or, in extreme cases, explosion and/or fire can result.

a) Keep batteries out of the reach of children

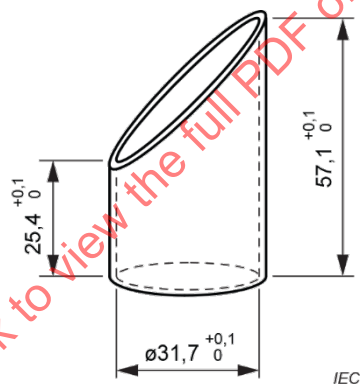
In particular, keep batteries which are considered swallowable out of the reach of children, particularly those batteries fitting within the limits of the ingestion gauge as defined in Figure 8. In case of ingestion of a cell or battery, seek medical assistance promptly. Swallowing coin cells or batteries can cause chemical burns, perforation of soft tissue, and, in severe cases, can cause death. They need to be removed immediately if swallowed. See Figure 9 for an example of appropriate warning text.

Warning text similar to Figure 9 may be used for safety information about battery handling. For cautionary advice and symbols to be printed on batteries and battery packaging refer to Clause 9.

NOTE 1 Child-resistant packaging according to Annex E is intended to help keep coin cells out of the reach of children before use.

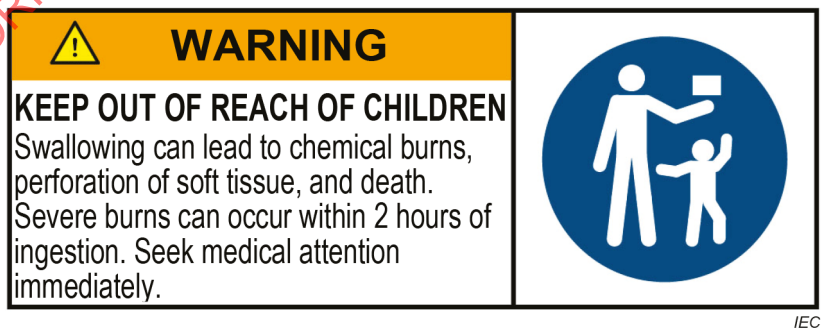
NOTE 2 Refer to [13] for general information on hazards from batteries.

Dimensions in millimetres



[SOURCE: ISO 8124-1 [18]]

Figure 8 – Ingestion gauge



NOTE This product safety label is compliant with [16].

Figure 9 – Example for warning against swallowing, particularly coin cell batteries

b) Do not allow children to replace batteries without adult supervision

c) Always insert batteries correctly with regard to polarity (+ and –) marked on the battery and the equipment

When batteries are inserted in reverse they might be short-circuited or charged. This can cause overheating, leakage, venting, rupture, explosion, fire and personal injury.

d) Do not short-circuit batteries

When the positive (+) and negative (–) terminals of a battery are in electrical contact with each other, the battery becomes short-circuited. For example loose batteries in a pocket with keys or coins, can be short-circuited. This can result in venting, leakage, explosion, fire and personal injury.

e) Do not charge batteries

Attempting to charge a non-rechargeable (primary) battery can cause internal gas and/or heat generation resulting in leakage, venting, explosion, fire and personal injury.

f) Do not force discharge batteries

When batteries are force discharged by means of an external power source, the voltage of the battery will be forced below its design capability and gases will be generated inside the battery. This can result in leakage, venting, explosion, fire and personal injury.

g) Do not mix new and used batteries or batteries of different types or brands

When replacing batteries, replace all of them at the same time with new batteries of the same brand and type. When batteries of different brand or type are used together or new and used batteries are used together, some batteries might be over-discharged / force discharged due to a difference of voltage or capacity. This can result in leakage, venting, explosion or fire, and can cause personal injury.

h) Exhausted batteries should be immediately removed from equipment and properly disposed of

When discharged batteries are kept in the equipment for a long time, electrolyte leakage can occur causing damage to the equipment and/or personal injury.

i) Do not heat batteries

When a battery is exposed to heat, leakage, venting, explosion or fire can occur and cause personal injury.

j) Do not weld or solder directly to batteries

The heat from welding or soldering directly to a battery can cause leakage, venting, explosion or fire, and can cause personal injury.

k) Do not dismantle batteries

When a battery is dismantled or taken apart, contact with the components can be harmful and can cause personal injury or fire.

l) Do not deform batteries

Batteries should not be crushed, punctured, or otherwise mutilated. Such abuse can cause leakage, venting, explosion or fire, and can cause personal injury.

m) Do not dispose of batteries in fire

When batteries are disposed of in fire, the heat build-up can cause explosion and/or fire and personal injury. Do not incinerate batteries except for approved disposal in a controlled incinerator.

n) A lithium battery with a damaged container should not be exposed to water

Lithium metal in contact with water can produce hydrogen gas, fire, explosion and/or cause personal injury.

o) Do not encapsulate and/or modify batteries

Encapsulation or any other modification to a battery can result in blockage of the pressure relief mechanism(s) and subsequent explosion and personal injury. Advice from the battery manufacturer should be sought if it is considered necessary to make any modification.

p) Store unused batteries in their original packaging away from metal objects. If already unpacked, do not mix or jumble batteries

Unpacked batteries could get jumbled or get mixed with metal objects such as keys, coins, etc. This can cause battery short-circuiting which can result in leakage, venting, explosion or fire, and personal injury. One of the best ways to prevent this from happening is to store unused batteries in their original packaging.

q) Remove batteries from equipment if it is not to be used for an extended period of time unless it is for emergency purposes

It is advantageous to remove batteries immediately from equipment which has ceased to function satisfactorily, or when a long period of disuse is anticipated (e.g. camcorders, digital cameras, photoflash, etc.). Although most lithium batteries on the market today are highly leak resistant, a battery that has been partially or completely exhausted might be more prone to leak than one that is unused.

7.3 Additional information for safety of coin cells

Additional information for safety of coin cells is provided by consumer safety organisations as well as battery manufacturers' associations. When searching for such information, it should be noted that the term "coin cell" is not used in most languages other than English, and the distinction between a cell and a battery is often not made in the literature. Therefore, the term "lithium button cell" has been proposed as an alternative to the term "coin cell" and the terms "coin battery" and "lithium button battery" have been proposed as alternatives to the terms “coin cell" and "lithium button cell". The terms "coin cell" and "coin battery” are only used in English. In languages other than English, the term "lithium button cell" is used instead of the term "coin cell" and the term "lithium button battery" is used instead of the term “coin battery”.

7.4 Packaging

The packaging shall be adequate to avoid mechanical damage during transport, handling and stacking. The materials and packaging design shall be chosen so as to prevent the development of unintentional electrical contact, short-circuit, shifting and corrosion of the terminals, and afford some protection from the environment.

7.5 Handling of battery cartons

Battery cartons should be handled with care. Rough handling might result in batteries being short-circuited or damaged. This can cause leakage, explosion, or fire.

7.6 Transport

7.6.1 General

Regulations concerning international transport of lithium batteries are based on the UN Recommendations on the Transport of Dangerous Goods [20].

Regulations for transport are subject to change. For the transport of lithium batteries, the latest editions of the following regulations should be consulted.

Testing requirements are defined in the UN Manual of Tests and Criteria [21]. As regulations are subject to change, the latest editions should be consulted.

For reference, transportation tests are also given in IEC 62281.

7.6.2 Air transport

Regulations concerning air transport of lithium batteries are specified in the Technical Instructions for the Safe Transport of Dangerous Goods by Air published by the International Civil Aviation Organization (ICAO) [2] and in the Dangerous Goods Regulations published by the International Air Transport Association (IATA) [1].

7.6.3 Sea transport

Regulations concerning sea transport of lithium batteries are specified in the International Maritime Dangerous Goods (IMDG) Code published by the International Maritime Organization (IMO) [12].

7.6.4 Land transport

Regulations concerning road and railroad transport are specified on a national or multilateral basis. While an increasing number of regulators adopt the UN Model Regulations [20], it is recommended that country-specific transport regulations be consulted before shipping.

7.7 Display and storage

a) Store batteries in well ventilated, dry and cool conditions

High temperature or high humidity can cause deterioration of the battery performance and/or surface corrosion.

b) Do not stack battery cartons on top of each other exceeding a specified height

If too many battery cartons are stacked, batteries in the lowest cartons might be deformed and electrolyte leakage can occur.

c) Avoid storing or displaying batteries in direct sun or in places where they get exposed to rain

When batteries get wet, their insulation resistance might be impaired and self-discharge and corrosion can occur. Heat can cause deterioration.

d) Store and display batteries in their original packaging

When batteries are unpacked and mixed they can be short-circuited or damaged.

See Annex C for additional details.

7.8 Disposal

Batteries may be disposed of via communal refuse arrangements provided no local rules to the contrary exist.

During transport, storage and handling for disposal, the following precautions should be considered:

a) Do not dismantle batteries

Some ingredients of lithium batteries might be flammable or harmful. They can cause injuries, fire, rupture or explosion.

b) Do not dispose of batteries in fire except under conditions of approved and controlled incineration

Lithium burns violently. Lithium batteries can explode in a fire. Combustion products from lithium batteries can be toxic and corrosive.

c) Store collected batteries in a clean and dry environment out of direct sunlight and away from extreme heat

Dirt and wetness might cause short-circuits and heat. Heat might cause leakage of flammable gas. This can result in fire, rupture or explosion.

d) Store collected batteries in a well-ventilated area

Used batteries might contain a residual charge. If they are short-circuited, abnormally charged or force discharged, leakage of flammable gas might be caused. This can result in fire, rupture or explosion.

e) Do not mix collected batteries with other materials

Used batteries might contain residual charge. If they are short-circuited, abnormally charged or force discharged, the generated heat can ignite flammable wastes such as oily rags, paper or wood and cause a fire.

f) Protect battery terminals

Protection of terminals should be considered by providing insulation, particularly for those batteries with a high voltage. Unprotected terminals might cause short-circuits, abnormal charging and forced discharge. This can result in leakage, fire, rupture or explosion.

8 Instructions for use

a) Always select the correct size and type of battery most suitable for the intended use. Information provided with the equipment to assist correct battery selection should be retained for reference.

b) Replace all batteries of a set at the same time.

c) Clean the battery contacts and also those of the equipment prior to battery installation.

d) Ensure that the batteries are installed correctly with regard to polarity (+ and –).

e) Remove exhausted batteries promptly.

9 Marking and packaging

9.1 General

In general, batteries shall be marked with the following information:

a) designation, IEC or common;

b) expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code;

c) polarity of the positive (+) terminal;

d) nominal voltage;

e) name or trademark of the manufacturer or supplier;

f) cautionary advice.

9.2 Marking of batteries too small to accommodate all markings

Some batteries have a surface too small to accommodate all markings shown in 9.1. For these batteries the designation 9.1 a) and the polarity 9.1 c) shall be marked on the battery, while all other markings shown in 9.1 may be given on the immediate packaging instead of on the battery.

See Table 9 for a summary of the marking requirements.

9.3 Additional requirements for swallowable coin cells and batteries

For swallowable coin cells and batteries, i.e. those that fit entirely within the ingestion gauge (Figure 8), that are intended for direct sale in consumer replaceable applications, caution for ingestion shall also be marked on the immediate packaging:

a) caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F.

Swallowable coin cells and batteries that are intended for direct sale in consumer replaceable applications and have a diameter of 16 mm or more shall be packaged in:

b) child resistant packaging.

Refer to Table 10 for a summary of the additional marking and packaging requirements for swallowable coin cells and batteries.

Table 9 – Marking requirements

List item	General	Batteries too small to accommodate all markings
a) Designation, IEC or common	A	A
b) Expiration of a recommended usage period or year and month or week of manufacture. The year and month or week of manufacture may be in code	A	B
c) Polarity of the positive (+) terminal	A	A
d) Nominal voltage	A	B
e) Name or trademark of the manufacturer or supplier	A	B
f) Cautionary advice	A	B
Key: A: Shall be marked on the battery B: May be marked on the immediate packaging instead of on the battery		

Table 10 – Additional marking and packaging requirements for swallowable coin cells and batteries

List item	Swallowable coin cells and batteries		
	d < 16 mm	16 mm ≤ d < 20 mm	d ≥ 20 mm
a) Caution for ingestion of swallowable batteries, see also 7.2 a) and Annex F	P	A and P	A and P
b) Child resistant packaging	NR	R	R

Key:

d: Diameter

A: Shall be marked on the battery

P: Shall be marked on the immediate packaging

R: Required

NR: Not required

NOTE 1 The requirements in this table apply only when batteries are intended for direct sale in consumer replaceable applications (see 9.3).

NOTE 2 The table does not include cylindrical cells and batteries because – although they may be swallowable – they would pass the oesophagus without causing harm.

9.4 Safety pictograms

Safety pictograms that could be considered for use as an alternative to written cautionary advice are provided in Annex D.

Annex A
(informative)

Guidelines for the achievement of safety of lithium batteries

The guidelines given in Figure A.1 were followed during the development of high power batteries for consumer use. They are given here for information.

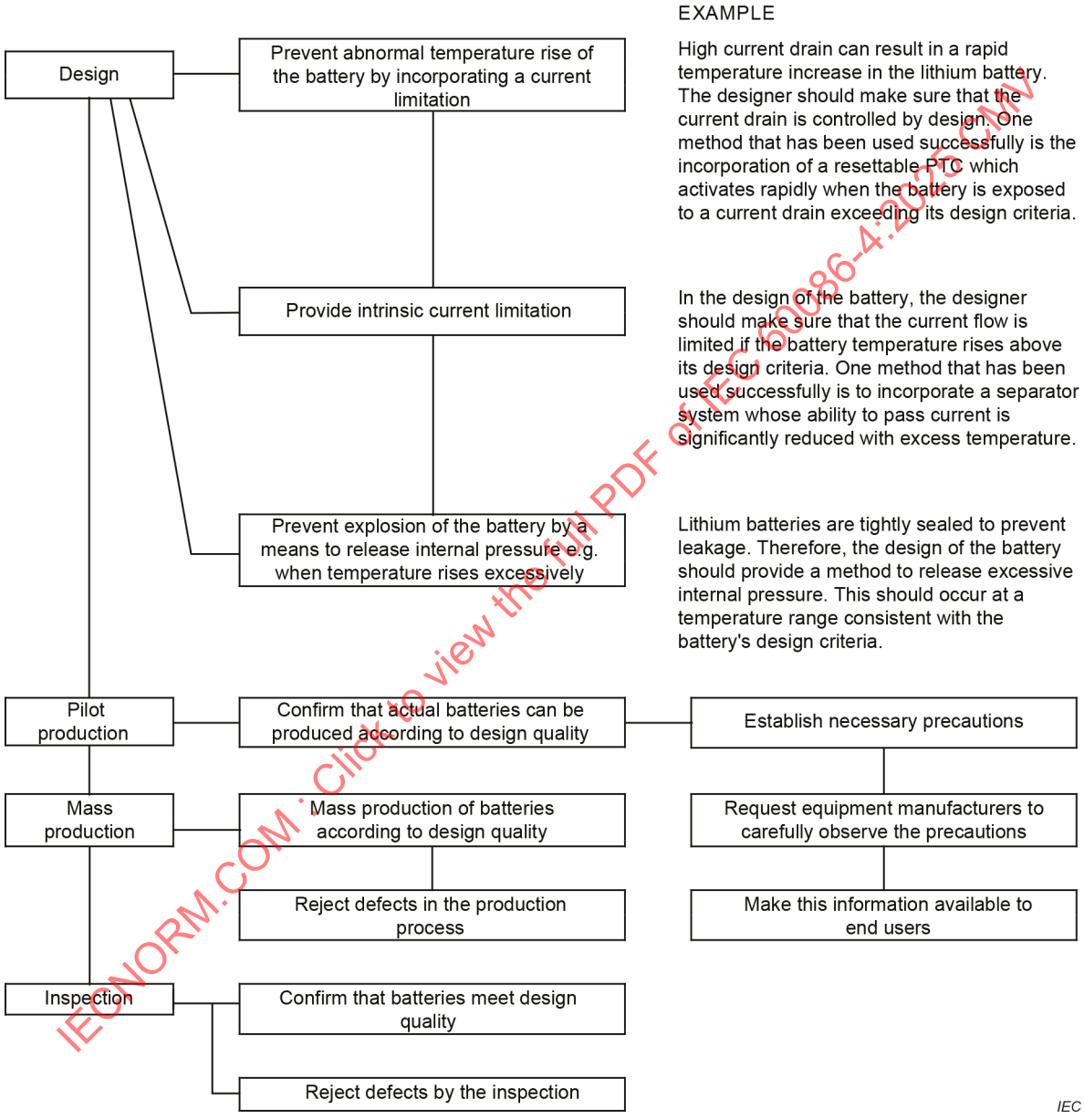


Figure A.1 – Battery design guidelines

Annex B
(informative)

Guidelines for designers of equipment using lithium batteries

Table B.1 represents a typical, but non-exhaustive, list of good advice to be provided by the manufacturer of primary lithium cells and batteries to equipment manufacturers and battery assemblers (see also IEC 60086-5:2021, Annex B ([8]), for guidelines for the design of battery compartments).

Table B.1 – Equipment design guidelines

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(1) When a lithium battery is used as main power source	(1.1) Selection of a suitable battery	Select most suitable battery for the equipment, taking note of its electrical characteristics	Battery might overheat
	(1.2) Number of batteries (series connection or parallel[a] connection) to be used and method of use	a) Multicell batteries (2CR5, CR-P2, 2CR13252 and others); one piece only	If the capacity of batteries in series connection is different, the battery with the lower capacity will be overdischarged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Cylindrical batteries (CR17345 and others); no more than two pieces	
		c) Coin type batteries (CR2016, CR2025, CR11108 and others); no more than two pieces	
		d) When more than one battery is used, different types should not be used in the same battery compartment	
		e) When batteries are used in parallel[a] protection against charging should be provided	If the voltages of batteries in parallel connection are different, the battery with the lower voltage will become charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(1.3) Design of battery circuit	a) Battery circuit should be isolated from any other power source	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
		b) Protective devices such as fuses should be incorporated in the circuit	Short-circuiting a battery can result in electrolyte leakage, overheating, rupture, explosion or fire
(2) When a lithium battery is used as back-up power source	(2.1) Design of battery circuit	The battery should be used in a separate circuit so that it is not force discharged or charged by the main power source	Battery might be over-discharged to reverse polarity or charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire
	(2.2) Design of battery circuit for memory back-up application	When a battery is connected to the circuit of a main power source with the possibility of being charged, a protective circuit is necessary with a combination of diode and resistor. The accumulated amount of the leakage current of the diode should be below 2 % of the battery capacity during expected life time	Battery might be charged. This can result in electrolyte leakage, overheating, rupture, explosion or fire

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(3) Battery holder and battery compartment		a) Battery compartments should be designed so that if a battery is reversed, open circuit is achieved. Battery compartments should be clearly and permanently marked to show the correct orientation of batteries	Unless protection is provided against battery reversal, damage to equipment can occur from resultant electrolyte leakage, overheating, rupture, explosion or fire
		b) Battery compartments should be designed so that batteries other than the specified size cannot be inserted and make contact	Equipment might be damaged or might not operate
		c) Battery compartments should be designed to allow generated gases to escape	Battery compartments might be damaged when internal pressure of the battery becomes too high due to gas generation
		d) Battery compartments should be designed to be water proof	
		e) Battery compartments should be designed to be explosion proof when tightly sealed	
		f) Battery compartments should be isolated from heat generated by the equipment	Battery might be deformed and leak electrolyte due to excessive heat
		g) Battery compartments should be designed so that they cannot easily be opened by children	Children might remove batteries from the compartment and swallow them
(4) Contacts and terminals		a) Material and shape of contacts and terminals should be selected so that effective electric contact is maintained	Heat might generate at the contact due to insufficient connection
		b) Auxiliary circuit should be designed to prevent reverse installation of batteries	Equipment might be damaged or might not operate
		c) Contact and terminal should be designed to prevent reverse installation of batteries	Equipment might be damaged. Battery might cause electrolyte leakage, overheating, rupture, explosion or fire
		d) Direct soldering or welding to a battery should be avoided	Battery might leak, overheat, rupture, explode or catch fire

Item	Sub-item	Recommendations	Possible consequences if the recommendations are not observed
(5) Indication of necessary precautions	(5.1) On the equipment 	a) Orientation of batteries (polarity) should be clearly indicated at the battery compartment	When a battery is inserted reverse and charged, it can result in electrolyte leakage, over-heating, rupture, explosion or fire
		b) The graphical symbol according to IEC 60417-5639 (2002-10) "rechargeable battery" [26] should be applied on battery chargers close to the battery compartment so as to indicate that only rechargeable batteries shall be inserted.	When non-rechargeable batteries are inserted in battery chargers, an explosion risk exists.
	(5.2) In the instruction manual 	a) Precautions for the proper handling of batteries should be indicated	Batteries might be mishandled and cause accidents
		b) The graphical symbol according to IEC 60417-5639 (2002-10) "rechargeable battery" [26] should be shown and explained in the instruction manuals of battery chargers so as to indicate that only rechargeable batteries shall be inserted.	When non-rechargeable batteries are inserted in battery chargers, an explosion risk exists. Batteries marked as "non-rechargeable" shall not be inserted.
		c) Instruction manuals generally should follow the principles layed down in [27].	

[a] See 7.1.3.

Annex C
(informative)

Additional information on display and storage

This Annex C provides additional details concerning display and storage of lithium batteries to those already given in 7.7.

The storage area should be clean, cool, dry, ventilated and weatherproof.

For normal storage, the temperature should be between +10 °C and +25 °C and should never exceed +30 °C. Extremes of humidity (over 95 % and below 40 % relative humidity) for sustained periods should be avoided since they are detrimental to both batteries and packaging. Batteries should therefore not be stored next to radiators or boilers nor in direct sunlight.

Although the storage life of batteries at room temperature is excellent, storage is improved at lower temperatures provided that special precautions are taken. The batteries should be enclosed in special protective packaging (such as sealed plastic bags or variants) which should be retained to protect the batteries from condensation during the time they are warming to ambient temperature. Accelerated warming is harmful.

Batteries which have been cold-stored may be put into use after return to ambient temperature.

Batteries may be stored fitted in equipment or packaging, if determined suitable by the battery manufacturer.

The height to which batteries may be stacked is clearly dependent on the strength of the packaging. As a general rule, this height should not exceed 1,5 m for cardboard packaging or 3 m for wooden cases.

The above recommendations are equally valid for storage conditions during prolonged transit. Thus, batteries should be stored away from ship engines and not left for long periods in unventilated metal box cars (containers) during summer.

Batteries should be dispatched promptly after manufacture and in rotation to distribution centres and on to the users. In order that stock rotation (first in, first out) can be practised, storage areas and displays should be properly designed and packs adequately marked.

Annex D
(informative)

Safety pictograms

D.1 General

Cautionary advice to fulfil the marking requirements in this document has, on a historical basis, been in the form of written text. In recent years, there has been a growing trend toward the use of pictograms as a complementary or alternative means of product safety communication.

The objectives of this Annex D are: (1) to establish uniform pictogram recommendations that are tied to long-used and specific written text, (2) to minimize the proliferation of safety pictogram designs, and (3) to lay the foundation for the use of safety pictograms instead of written text to communicate product safety and cautionary statements.

NOTE The design of these safety pictograms basically follows the design principles laid down in [15] and [17]. It was, however, adjusted to the limitations existing for battery marking.

D.2 Pictograms

The pictogram recommendations and cautionary advice are given in Table D.1.

Table D.1 – Safety pictograms

Reference	Safety pictogram	Cautionary advice
A		DO NOT CHARGE
B		DO NOT DEFORM OR DAMAGE
C		DO NOT DISPOSE OF IN FIRE
D		DO NOT INSERT INCORRECTLY

Reference	Safety pictogram	Cautionary advice
E		KEEP OUT OF REACH OF CHILDREN NOTE 1 See 7.2a) for critical safety information. NOTE 2 This pictogram is taken from ISO 7010-M055 (2020-11) [17], modified – arrow removed. The blue colour and the arrow of the ISO safety sign are not required. NOTE 3 See also Annex F.
F		DO NOT MIX DIFFERENT TYPES OR BRANDS
G		DO NOT MIX NEW AND USED
H		DO NOT OPEN OR DISMANTLE
I		DO NOT SHORT CIRCUIT
J		INSERT CORRECTLY
NOTE The grey shading highlights a white margin appearing when the pictogram is printed on coloured or black background.		

D.3 Instruction for use

The following instructions are provided for use of the safety pictograms.

a) Safety pictograms should be clearly legible. With the exception of pictogram E, they should have a diameter of 5 mm or larger.

b) Whilst colours are permitted, they should not detract from the information displayed. If colours are used, the circle and diagonal bar of pictograms A to D and F to I should be red and the background of pictograms E and J should be blue.

c) Not all of the safety pictograms need to be used together for a particular type or brand of battery. In particular, safety pictograms D and J are meant as alternatives for a similar purpose.

Annex E
(normative)

Child resistant packaging of coin cells

E.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its battery voltage causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

NOTE Accidental ingestion of coin batteries with a diameter of less than 16 mm is unlikely to cause serious chemical burns as they naturally pass through the oesophagus and gastrointestinal tract. It is established medical practice to monitor them until they get past the oesophagus and then allow them to naturally pass through the digestive tract.

This annex provides an approach for child resistant packaging of coin cells in order to help in preventing their accidental ingestion. This annex is not intended to supersede established national and international standards utilizing child panel package resistance testing, e.g. packaging requirements as specified in any of [23], [24], or [25].

E.2 Applicability

The following applies to consumer type coin cells with a diameter of 16 mm and larger.

a) Single cell packaging

   The packaging for coin cells shall meet one of the following conditions:

   i) Packaging requirements specified in any of [23], [24], or [25];

      or

   ii) The packaging strength shall be such that the packaging passes the tests described in E.3.

b) Multi-cell packaging

   Each cell containment in a multi-cell packaging shall be in compliance with a) even when another cell containment is removed from the packaging.

E.3 Packaging tests

E.3.1 General

The following test methods were developed based on the analysis of the behaviour of children in a test where they were required to try and open coin cell packaging within a limited time. The tests shall be conducted by an instructed person or, alternatively, if necessary, using suitable equipment.

E.3.2 Test items

a) Bending test

Hold the packaging with the fingers of one hand and hold the cell with the fingers of the other hand. Bend the packaging close to the battery until one hand touches the other hand as shown in Figure E.1. The bending angle should be minimum 150°.

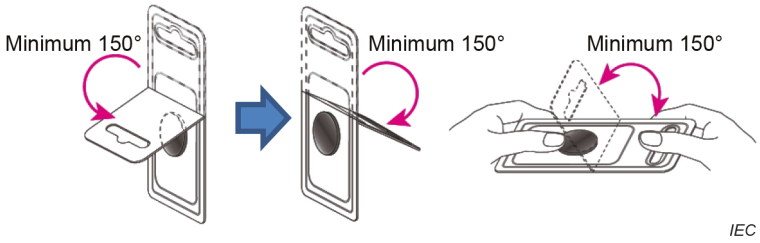


Figure E.1 – Bending test

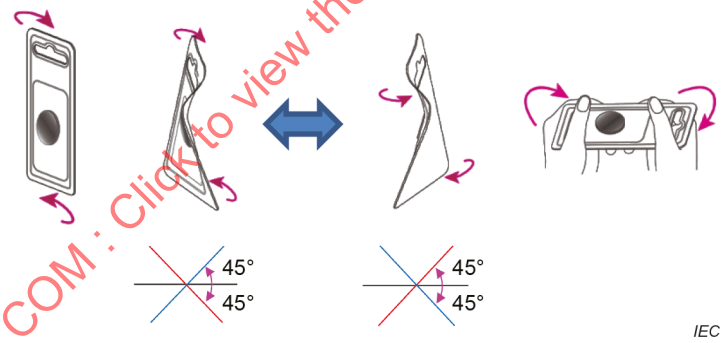
b) Torsion test

Hold the packaging with the fingers of one hand on each of its shorter sides and twist it diagonally with a torsion angle of 45° ± 5° in opposite directions as shown in Figure E.2, three times in both directions:

Step 1 Hold the packaging with the fingers of one hand on each of its shorter sides from the state of 0 degrees (neutral state without torsion). Twist it diagonally with a torsion angle of 45° in opposite directions as shown in Figure E.2.

Step 2 Twist it diagonally 90° (45° back and 45° opposite direction) in opposite directions to the direction twisted at the first time.

Step 3 Return to neutral state without torsion (45° back).



NOTE The red and blue lines represent the top and bottom edge of the packaging.

Figure E.2 – Torsion test

c) Tearing test

Try to tear the cell compartment with the fingers as shown in Figure E.3. Alternatively use suitable equipment and apply a force of at least 25 N.

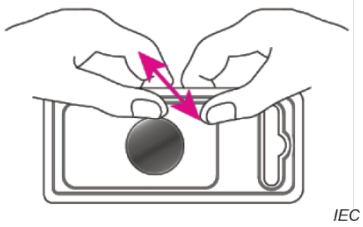


Figure E.3 – Tearing test

d) Pushing test

Try to push the cell out of the compartment with the fingers. Alternatively pull with a mass of at least 5 kg for 30 s; as shown in Figure E.4.

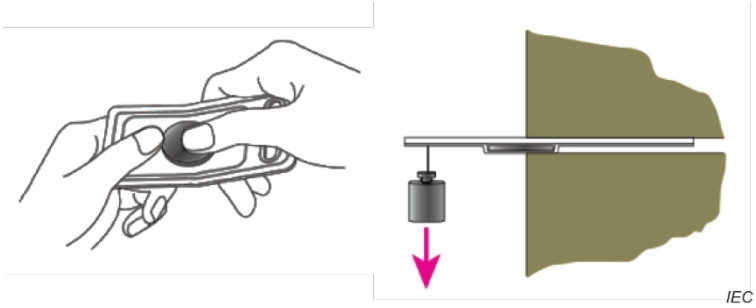


Figure E.4 – Pushing test

E.3.3 Test procedure

Sample packages shall be tested in the condition of the packaging as sold to the consumer. The number of test samples shall be 10 packages. Each sample shall be subjected to a series of tests in the order and frequence outlined in Table E.1.

Table E.1 – Test procedure

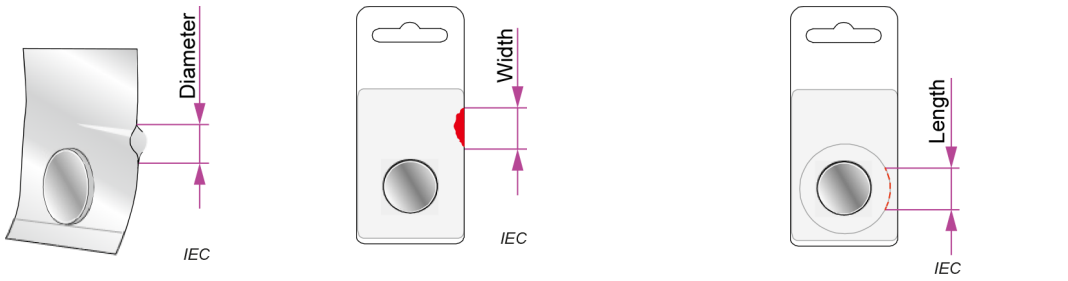
Order	Test item		Number of times
(1)	a)	Bending test	50
(2)	b)	Torsion test	25
(3)	c)	Tearing test	1
(4)	b)	Torsion test	25
(5)	a)	Bending test	50
(6)	c)	Tearing test	1
(7)	d)	Pushing test	1

E.3.4 Criteria

Each test sample shall meet the following criteria.

a) Each cell shall be kept in its packaging until the end of the test series, and

b) In order to prevent a child from pulling the cell out from its compartment, the packaging shall not open too wide. The maximum allowable size of an opening in the packaging is 6 mm diameter for a round hole (see Figure E.5 a) for an example) and 10 mm width for a slit (see Figure E.5 b) for an example). If the perimeter of the cell itself is protected, the maximum allowable length of an arc-shaped opening in the primary protective seal around the cell is 10 mm (see Figure E.5 c) for an example).



a) Round hole b) Slit c) Arc in primary protective seal

Figure E.5 – Maximum packaging opening

Annex F
(normative)

Use of the KEEP OUT OF REACH OF CHILDREN safety sign

F.1 General

Accidental ingestion of coin cells has become an object of public concern. When a coin cell gets stuck in the oesophagus, its battery voltage causes the electrolysis of water and the generation of hydroxide ions. These hydroxide ions form a strong alkaline solution and can cause chemical burns, perforation of soft tissue, and in severe cases can cause death.

The purpose of the safety sign KEEP OUT OF REACH OF CHILDREN is to give parents who have children a heads-up as a mandatory action sign even if intended products are safe in the usual sense of adults.

Therefore, the purpose of the safety sign is to convey the message that these products shall be kept out of reach of children in order to prevent accidental ingestion.

F.2 Safety sign

When a safety sign is used to convey the message that these products shall be kept out of reach of children, the following applies. The safety sign recommendation and cautionary advice for use on batteries and battery packaging are given in Table D.1, safety sign E, while warning text for safety information about battery handling is given in Figure 9.

F.3 Marking on the packaging

a) Refer to Table 10 for marking requirements on packaging.

b) The safety sign shall appear on contrasting background. The background shall cover at least 50 % of the area of the pictogram.

c) The size of the safety sign shall be such that the diameter is 6 mm or larger.

d) If the text KEEP OUT OF REACH OF CHILDREN is used, it shall contrast with the background color on which it is printed.

F.4 Marking on the cell

a) Refer to Table 10 for marking requirements on coin cells.

b) The safety sign shall be applied durably and indelibly. No colour is required. Engraving, etching, embossing or stamping are acceptable.

c) The safety sign on cells shall have a diameter of 6 mm or larger.

NOTE Alternative versions of the safety sign are shown in Figure F.1. The manufacturer can select any of them.

a) Type 1 **b) Type 2** **c) Type 3**

Figure F.1 – Safety signs for use on coin cells

Annex G
(normative)

Measures against misuse of batteries not intended for consumer replacement

G.1 Background

Lithium primary batteries are at risk of explosion or fire, if they are subjected to reverse (charging) current beyond the manufacturer's assumed current value (conditions deviating from Test I in 6.5.6).

Therefore, under any circumstances, lithium primary batteries must not be recharged.

However, with the advent of lithium secondary batteries and their chargers that are size-compatible with the lithium primary batteries standardised in IEC 60086-2, there is a risk that the lithium primary battery will be accidentally inserted into a battery charger.

In particular, lithium primary batteries not standardised in IEC 60086-2 are at risk of particularly serious accidents.

Batteries not standardised in IEC 60086-2 are generally not intended for consumer replacement[3] but are distributed only to equipment manufacturers and at most to specialist retailers and technically skilled consumers. They are generally rigidly soldered or permanently and unmistakeably connected to a circuit by means of a harness. Under no circumstances must they be inserted in battery compartments of equipment designed for battery replacement by the end consumer. This holds particularly for battery chargers.

Refer to 7.1.2 for safety measures which must be implemented when such batteries are incorporated into a circuit powered by an independent main power source.

The purpose of this annex is to identify such batteries and specify requirements for their marking, packaging, and placing on the market.

G.2 Additional measures for the prevention of confusion of primary batteries not intended for consumer replacement with secondary batteries

G.2.1 Identification of primary (non-rechargeable) batteries not intended for consumer replacement

Primary batteries are considered to present a particular risk when inserted in battery chargers if they have the following properties:

a) The battery belongs to voltage range 2 according to IEC 60086-1:2021, 4.1.7. This voltage range is characterized by a standard discharge voltage in the range from 2,72 V to 3,68 V; and

b) The battery is not specified in IEC 60086-2 but is dimensionally interchangeable with a battery type specified in IEC 60086-2; and

c) The battery meets one of the following conditions:

   i) The battery is not intended for consumer replaceable applications; or

   ii) The battery does not fulfil the design requirements of 4.1 c).

[3] Such batteries typically comply with the definition of industrial batteries in the European Batteries Regulation [28].

NOTE Batteries with harnesses or solder tags are not considered to be dimensionally interchangeable with their counterparts having no harnesses or solder tags.

G.2.2 Marking and information requirements for primary batteries not intended for consumer replacement

Primary batteries that have been identified according to G.2.1 as presenting a particular risk shall be placed on the market in such a way that they cannot end up in the reach of end users. They shall not be sold into applications where they can be replaced and inserted in equipment by the end user.

Where it cannot be prevented that such batteries end up in the reach of end users, the following additional measures shall be taken:

a) The batteries shall be packed individually in an immediate packaging, e.g. in a cardboard box or in a plastic bag; and

b) The batteries shall be marked visibly, legibly, and permanently according to the requirements of the local product safety legislation with an indication that they are not rechargeable and not intended for consumer replaceable applications; and

c) If this marking, due to lack of space, cannot be applied on the battery itself, the marking required in list item b) shall be confirmed on the immediate packaging; and

d) The indication according to list item b) shall also be applied in connection with offers for sale in such a way that it can easily be found and read. Offers for sale on the internet shall be set up in such a way that the buyer, before completing the purchase, has to confirm separately that he has read and understood the indication.

G.2.3 Information responsibility of manufacturers and distributors

Manufacturers and distributors of primary batteries that have been identified according to G.2.1 as presenting a particular risk shall inform their customers about the particular risk of these batteries and the requirements for their marking, e.g. by referring to Annex G of this document in the data sheets and in the shipping documents. Furthermore, they shall ensure in an appropriate manner that this information responsibility is passed on along the supply chain.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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PILES ÉLECTRIQUES –

Partie 4: Sécurité des piles au lithium

AVANT-PROPOS

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L'IEC 60086-4 a été établie par le comité d'études 35 de l'IEC: Piles. Il s'agit d'une Norme internationale.

Cette sixième édition annule et remplace la cinquième édition parue en 2019. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) ajout de définitions pour les concepts de fuite et de dégazage, en complément des critères d'essai;

b) révision de l'essai de décharge excessive;

c) révision des exigences de marquage;

d) révision des critères relatifs à l'essai des emballages à l'épreuve des enfants;

e) modification de l'objet de l'Annexe F, passant de "informative" à "normative";

f) ajout d'une Annexe G stipulant des mesures supplémentaires contre le mauvais usage des piles qui ne sont pas destinées à être remplacées par le consommateur;

g) intégration du contenu de la Feuille d'Interprétation 1 (IEC 60086-4:2019/ISH1:2020);

h) réordonnancement des termes énumérés à l'Article 3 selon leurs fonctions: termes de base, systèmes électrochimiques, formes de piles, tailles de piles, caractéristiques électriques, spécifications, considérations relatives à la sécurité, modes de défaillance;

i) en 6.4.4, réduction de l'exemption d'accélération pour l'essai de chocs des piles au lithium, passant de 12 kg à 4,482 kg, afin de refléter le fait qu'il s'agit du seuil défini pour l'essai T-4 de l'IEC 62281, dans lequel l'accélération maximale descend en dessous de 150 g_n.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
35/1571/FDIS	35/1579/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications.

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Une liste de toutes les parties de la série IEC 60086, publiées sous le titre général *Piles électriques*, se trouve sur le site Web de l'IEC.

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INTRODUCTION

La notion de sécurité est étroitement liée à la sauvegarde de l'intégrité des personnes et des biens. Le présent document spécifie les essais et les exigences pour les piles au lithium, et a été établi conformément aux lignes directrices ISO/IEC, en prenant en compte toutes les normes nationales et internationales qui s'appliquent.

Les piles au lithium sont différentes des piles électriques conventionnelles utilisant un électrolyte aqueux, dans la mesure où elles contiennent des matériaux inflammables.

Par conséquent, il est important de bien prendre en compte la sécurité aux étapes que sont la conception, la production, la distribution, l'utilisation et la mise au rebut des piles au lithium. Compte tenu de leurs caractéristiques spécifiques, les piles au lithium pour les applications grand public étaient à l'origine de petite taille et de faible puissance. Il existait également des piles au lithium de forte puissance qui étaient utilisées pour des applications industrielles et militaires particulières, dont l'une des particularités était d'être "remplaçables par un technicien". La première édition du présent document avait été rédigée pour prendre en compte cette situation.

Cependant, depuis la fin des années 1980 environ, des piles au lithium de forte puissance ont commencé à être largement utilisées sur le marché des piles remplaçables par le consommateur, principalement en tant que source d'énergie dans les appareils de prise de vue. La demande pour de telles piles au lithium de forte puissance ayant augmenté de manière significative, différents fabricants ont commencé à en produire. Par conséquent, les considérations relatives à la sécurité des piles au lithium de forte puissance ont été incluses dans la seconde édition du présent document.

Les piles au lithium, tant pour les applications grand public que pour les applications industrielles, sont des produits du marché dont la sûreté et la fiabilité sont bien établies, cela étant dû, au moins en partie, à l'existence de normes de sécurité telles que le présent document, ainsi que l'IEC 62281 pour le secteur du transport. La quatrième édition du présent document ne reflétait que les modifications mineures qui étaient devenues nécessaires pour qu'elle reste harmonisée avec l'IEC 62281, et pour continuer à améliorer les informations destinées à l'utilisateur en ce qui concerne la sécurité.

Des lignes directrices relatives aux questions de sécurité inhérentes à la conception des piles au lithium sont données à l'Annexe A. L'Annexe B donne des lignes directrices relatives aux questions de sécurité inhérentes à la conception des matériels dans lesquels sont installées des piles au lithium. L'Annexe A ainsi que l'Annexe B reflètent l'expérience acquise avec les piles au lithium utilisées dans les applications pour les appareils de prise de vue et sont fondées sur le document de référence [22][1].

Le danger d'ingestion des piles boutons est devenu un problème et a été traité dans les cinquièmes et sixièmes éditions du présent document par plusieurs mesures indépendantes, telles que le développement d'une nouvelle signalétique de sécurité "TENIR À L'ÉCART DES ENFANTS", ainsi que l'introduction d'emballages à l'épreuve des enfants.

Une nouvelle Annexe G stipule des mesures contre le mauvais usage des éléments et piles qui ne sont pas destinés à être remplacés par le consommateur.

1 Les chiffres entre crochets se réfèrent à la Bibliographie.

La sécurité est l'absence de risques inacceptables. La sécurité absolue ne peut pas exister: il subsiste toujours un risque. De ce fait, la sécurité d'un produit, d'un procédé ou d'un service ne peut être que relative. La sécurité est obtenue en réduisant le risque à un niveau tolérable, déterminé par la recherche d'un équilibre optimal entre l'idéal de sécurité absolue et les exigences auxquelles doit répondre un produit, un procédé ou un service, et des facteurs tels que le bénéfice pour l'utilisateur, l'adéquation à l'usage prévu, la rentabilité et les conventions de la société concernée.

Dans la mesure où la sécurité pose toutes sortes de problèmes, il est impossible d'établir une liste de dispositions et de recommandations précises qui s'appliquent dans tous les cas. Cependant, s'il est suivi de manière judicieuse en fonction de son applicabilité, le présent document constitue une référence raisonnable et cohérente en ce qui concerne la sécurité.

PILES ÉLECTRIQUES –

Partie 4: Sécurité des piles au lithium

1 Domaine d'application

La présente partie de l'IEC 60086 spécifie les essais et les exigences pour les piles électriques au lithium afin d'assurer leur fonctionnement en toute sécurité dans les conditions d'utilisation prévue et en cas de mauvais usage raisonnablement prévisible.

NOTE Les piles électriques au lithium qui sont normalisées dans l'IEC 60086-2 sont prévues pour satisfaire à toutes les exigences applicables ci-dessous. Il est entendu que la présente partie de l'IEC 60086 est également susceptible d'être prise en compte pour mesurer les piles électriques au lithium non normalisées et/ou s'assurer de leur sécurité. Dans les deux cas, il n'existe aucune déclaration ou garantie que la conformité ou la non-conformité à la présente partie de l'IEC 60086 répondra ou ne répondra pas aux objectifs ou aux besoins particuliers de l'utilisateur.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60086-1:2021, *Piles électriques – Partie 1: Généralités*

IEC 60086-2, *Piles électriques – Partie 2: Spécifications physiques et électriques*

IEC 62281, *Sécurité des piles et des accumulateurs au lithium pendant le transport*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

NOTE Certaines définitions tirées de l'IEC 60050-482, de l'IEC 60086-1 et du Guide ISO/IEC 51 sont répétées ci-après, dans un souci de commodité.

3.1
élément
unité fonctionnelle de base, consistant en un assemblage d'électrodes, d'électrolyte, de conteneur, de bornes et généralement de séparateurs, qui est une source d'énergie électrique obtenue par transformation directe d'énergie chimique

[SOURCE: IEC 60050-482:2004, 482-01-01]

3.2
pile
un ou plusieurs éléments raccordés électriquement et placés dans un boîtier, avec des bornes, des marquages et des dispositifs de protection, etc., selon ce qui est nécessaire pour l'utilisation

[SOURCE: IEC 60050-482:2004, 482-01-04, modifié - L'expression "équipés des dispositifs nécessaires pour l'emploi, par exemple boîtier" a été remplacée par "raccordés électriquement et placés dans un boîtier", et l'expression "etc., selon ce qui est nécessaire pour l'utilisation" a été ajoutée.]

3.3
élément composant
élément contenu dans une pile

3.4
élément au lithium
élément contenant un électrolyte non aqueux et dont l'électrode négative est constituée de lithium ou en contient

[SOURCE: IEC 60050-482:2004 482-01-06, modifié - La note a été supprimée.]

3.5
élément bouton au lithium
pile bouton au lithium
petit élément ou petite batterie de forme ronde dont la hauteur totale est inférieure au diamètre, contenant de l'électrolyte non aqueux

Note 1 à l'Article: La tension nominale des piles au lithium est généralement supérieure à 2 V. Voir également la définition de "pile bouton" dans l'IEC 60086-5.

Note 2 à l'Article: Voir 7.3 pour la suggestion d'utilisation des termes en variante.

Note 3 à l'article: Dans la version anglaise, les termes "lithium button cell" (élément bouton au lithium) et "lithium button battery" (pile bouton au lithium) sont fournis comme des termes en variante pour "coin cell" (élément bouton lithium) et "coin battery" (pile bouton lithium), afin d'éviter d'utiliser les termes "button cell" (élément bouton) et "button battery" (pile bouton), qui induiraient le lecteur en erreur car leur signification est différente, voir la Partie 1 de cette série de normes.

Il convient par conséquent d'omettre les termes "coin cell" (élément bouton lithium) et "coin battery" (pile bouton lithium) dans les langues pour lesquelles ils n'ont pas d'équivalent littéral permettant de faire la distinction.

[SOURCE: IEC 60050-482:2004 482-02-40, modifié – Les termes ont été modifiés, la note à l'article a été remplacée par de nouvelles notes à l'article.]

3.6
élément cylindrique
pile cylindrique
élément rond ou pile ronde dans laquelle la hauteur totale est supérieure ou égale au diamètre

[SOURCE: IEC 60050-482:2004, 482-02-39, modifié - L'expression "élément de forme cylindrique" a été remplacée par "élément rond ou pile ronde".]

3.7
élément parallélépipédique
pile parallélépipédique
élément ou batterie ayant la forme d'un parallélépipède dont les faces sont rectangulaires

[SOURCE: IEC 60050-482:2004, 482-02-38]

3.8
grand élément
élément dont la masse brute est supérieure à 500 g

3.9
grande pile
pile dont la masse brute est supérieure à 12 kg

3.10
tension nominale
valeur approchée appropriée d'une tension, utilisée pour désigner ou identifier un élément, une pile, ou un système électrochimique

[SOURCE: IEC 60050-482:2004, 482-03-31]

3.11
tension en circuit ouvert
OCV, $U_{OC,}$ tension à vide
tension électrique aux bornes d'un élément ou d'une pile en l'absence de circulation de courant externe

[SOURCE: IEC 60050-482:2004, 482-03-32, modifié - Les termes en variante "OCV, $U_{OC,}$ tension à vide" ont été ajoutés, l'expression "quand le courant de décharge est nul" a été remplacée par "en l'absence de circulation de courant externe".]

3.12
capacité assignée
valeur de la capacité d'un élément ou d'une pile déterminée dans des conditions spécifiées et déclarée par le fabricant

[SOURCE: IEC 60050-482:2004, 482-03-15, modifié - L'expression "élément ou" a été ajoutée.]

3.13
profondeur de décharge
DOD
pourcentage de capacité assignée déchargée d'un élément ou d'une pile

Note 1 à l'article: L'abréviation "DOD" est dérivée du terme anglais développé correspondant "Depth Of Discharge".

3.14
non déchargé
état d'un élément ou d'une pile électrique à une profondeur de décharge de 0 %

3.15
complètement déchargé
état d'un élément ou d'une pile à une profondeur de décharge de 100 %

3.16
dommage
blessure physique ou atteinte à la santé des personnes, ou atteinte aux biens ou à l'environnement

[SOURCE: Guide ISO/IEC 51:2014, 3.1]

3.17
danger
source potentielle de dommage

[SOURCE: Guide ISO/IEC 51:2014, 3.2]

3.18
risque
combinaison de la probabilité de la survenue d'un dommage et de sa gravité

[SOURCE: Guide ISO/IEC 51:2014, 3.9, modifié - La note a été supprimée.]

3.19
sécurité
absence de risque intolérable

[SOURCE: Guide ISO/IEC 51:2014, 3.14]

3.20
utilisation prévue
utilisation conforme aux informations fournies avec un produit ou un système ou, en l'absence de telles informations, conforme aux profils d'utilisation généralement entendus

[SOURCE: Guide ISO/IEC 51:2014, 3.6]

3.21
mauvais usage raisonnablement prévisible
utilisation d'un produit, d'un procédé ou d'un système dans des conditions ou à des fins non prévues par le fournisseur, mais qui peut provenir d'un comportement humain envisageable

[SOURCE: Guide ISO/IEC 51:2014, 3.7, modifié - Les notes ont été supprimées.]

3.22
dispositif de protection
dispositifs tels que les fusibles, les diodes ou d'autres limiteurs de courant électriques ou électroniques, conçus pour interrompre la circulation du courant, bloquer la circulation du courant dans un sens ou limiter la circulation de courant dans un circuit électrique

3.23
fuite
échappement imprévu d'électrolyte, de gaz ou d'un autre matériau à partir d'un élément ou d'une pile

Note 1 à l'Article: Il convient de ne pas confondre le concept de fuite ainsi décrit avec les critères d'évaluation d'essai relatifs à l'identification d'une fuite, spécifiés à l'Article 6.

3.24
dégazage
libération d'un excédent de pression interne depuis un élément ou une pile, d'une manière ayant été prévue par la conception

Note 1 à l'Article: Il convient de ne pas confondre le concept de dégazage ainsi décrit avec les critères d'évaluation d'essai relatifs à l'identification d'un dégazage, spécifiés à l'Article 6.

4 Exigences relatives à la sécurité

4.1 Conception

Les piles au lithium sont classées en fonction de leur composition chimique (anode, cathode, électrolyte), de leur construction interne (bobine, spirale) et sont disponibles dans des configurations cylindriques, de type bouton, et parallélépipédiques. Il est nécessaire de prendre en compte toutes les considérations correspondantes relatives à la sécurité, au moment de la conception de la pile, en intégrant le fait qu'elles peuvent considérablement différer, en fonction du système au lithium mis en œuvre, de la puissance et de la configuration de la pile.

Les notions suivantes de conception visant à assurer la sécurité sont communes à toutes les piles au lithium:

a) un échauffement anormal dépassant la valeur critique définie par le fabricant doit être évité par la conception;

b) les augmentations de température à l'intérieur de la pile doivent être maîtrisées par une conception qui limite la circulation du courant;

c) les éléments et les piles au lithium doivent être conçus pour libérer des pressions internes excessives ou pour empêcher une rupture violente dans des conditions de transport, d'utilisation prévue et de mauvais usage raisonnablement prévisible.

Si, dans des cas particuliers, cette notion de conception ne peut pas être mise en œuvre, les exigences organisationnelles décrites dans l'Annexe G doivent s'appliquer.

Voir l'Annexe A pour les lignes directrices à suivre afin d'assurer la sécurité des piles au lithium.

4.2 Plan qualité

Le fabricant doit préparer et mettre en œuvre un plan qualité définissant les procédures pour le contrôle des matériaux, composants, éléments et piles au cours de la fabrication, devant être appliquées au processus complet de fabrication d'un type spécifique de pile. Il convient que les fabricants comprennent leurs capacités opérationnelles de processus et il convient qu'ils engagent les contrôles de processus nécessaires dans la mesure où ils sont liés à la sécurité des produits.

5 Essais de type et échantillonnage

5.1 Validité des essais

Les éléments ou les piles au lithium doivent être soumis aux essais conformément aux exigences du présent document. Les essais restent valides tant que la conception ou les exigences n'ont pas été modifiées. De nouveaux essais sont exigés lorsque:

a) une spécification de masse de pile varie de plus de 0,1 g ou 20 %, la plus grande des valeurs étant retenue, pour la cathode, l'anode ou l'électrolyte;

b) la modification d'une spécification d'une pile entraînerait un échec de l'un quelconque des essais;

c) de nouveaux essais ou de nouvelles exigences sont ajoutés; ou

d) la modification d'une exigence entraînerait un échec de l'un quelconque des essais.

5.2 Échantillons d'essai

Il convient de prélever des échantillons dans les lots de production conformément aux méthodes statistiques acceptées. Le nombre d'échantillons d'essai est donné dans le Tableau 1. Les mêmes éléments et piles d'essai sont utilisés pour les essais A à E successivement. Des éléments et des piles d'essai neufs sont exigés pour chacun des essais F à M.

Tableau 1 – Nombre d'échantillons d'essai

Essais	État de décharge		Éléments ou pile comportant un seul élément [a]	Piles comportant plusieurs éléments
Essais A à E	Non déchargé		10	4
	Complètement déchargé		10	4
Essai F ou G	Non déchargé		5	5 éléments composants
	Complètement déchargé		5	5 éléments composants
Essai H	Complètement déchargé		10	10 éléments composants
Essais I à K	Non déchargé		5	5
Essai L	Non déchargé		20[b]	n/a
Essai M	Prédéchargés à 50 %	Pile de type CR	10[c]	n/a
	Complètement déchargé	Pile de type CR	10[d]	n/a
	Prédéchargés à 50 %	Pile de type FR	20[e]	n/a
	Complètement déchargé	Pile de type FR	20[f]	n/a

Légende

n/a: non applicable

[a] Dans le cas des piles comportant un seul élément pour lesquelles un élément composant a été soumis à essai, de nouveaux essais ne sont pas exigés, sauf si la modification est susceptible de conduire à un échec de l'un quelconque des essais.

[b] Quatre piles connectées en série avec l'une des quatre piles inversée (5 ensembles).

[c] Deux piles de type CR connectées en série, l'une d'elles étant prédéchargée à 50 % (5 ensembles). L'échantillonnage des éléments non déchargés doit provenir d'un seul et même lot de production.

[d] Deux piles de type CR connectées en série, l'une d'elles étant complètement déchargée (5 ensembles). L'échantillonnage des éléments non déchargés doit provenir d'un seul et même lot de production.

[e] Quatre piles de type FR connectées en série, l'une d'elles étant prédéchargée à 50 % (5 ensembles). L'échantillonnage des éléments non déchargés doit provenir d'un seul et même lot de production.

[f] Quatre piles de type FR connectées en série, l'une d'elles étant complètement déchargée (5 ensembles). L'échantillonnage des éléments non déchargés doit provenir d'un seul et même lot de production.

6 Essais et exigences

6.1 Généralités

6.1.1 Matrice d'application d'essai

L'applicabilité des méthodes d'essai aux éléments et piles d'essai est présentée dans le Tableau 2.

Tableau 2 – Matrice d'application d'essai

Forme	Essais applicables												
	A	B	C	D	E	F	G	H	I	J	K	L	M
s	x	x	x	x	x	x [a]	x [a]	x	x	x	x	x [b]	x [c]
m	x	x	x	x	x	x [a, d]	x [a, d]	x [d]	x	x	x	n/a	n/a

Description des essais:		Légende:	
Essais relatifs à l'utilisation prévue A: Altitude B: Cycles thermiques C: Vibrations D: Chocs	Essais relatifs à de mauvais usages raisonnablement prévisibles E: Court-circuit extérieur F: Impact G: Écrasement H: Décharge forcée I: Charge anormale J: Chute libre K: Température élevée L: Installation incorrecte M: Décharge excessive	Forme s: m: Applicabilité x: n/a:	 élément ou pile comportant un seul élément pile comportant des éléments multiples applicable non applicable

[a] Un seul essai doit être appliqué, l'essai F ou l'essai G.

[b] Uniquement applicable aux modèles CR17345, CR15H270, FR14505 et aux piles de type similaire, de construction en spirale, susceptibles d'être installées de manière incorrecte et chargées.

[c] Uniquement applicable aux modèles CR17345, CR15H270, FR14505, FR10G445 et aux piles de type similaire, de construction en spirale, susceptibles de subir une décharge excessive.

[d] L'essai s'applique aux éléments composants.

6.1.2 Mise en garde

AVERTISSEMENT: Ces essais imposent l'utilisation de procédures qui peuvent entraîner des blessures si des précautions appropriées ne sont pas prises.

Lors de la rédaction de ces essais, il a été pris pour hypothèse qu'ils seraient réalisés par des techniciens suffisamment qualifiés et expérimentés, utilisant une protection appropriée.

6.1.3 Température ambiante

Sauf spécification contraire, les essais doivent être effectués à une température ambiante de 20 °C ± 5 °C.

6.1.4 Tolérances de mesure des paramètres

L'exactitude globale des valeurs contrôlées ou mesurées, par rapport aux paramètres spécifiés ou réels, doit se situer dans les tolérances suivantes:

a) ±1 % pour la tension;
b) ±1 % pour le courant;
c) ±2 °C pour la température;
d) ±0,1 % pour la durée;
e) ±1 % pour les dimensions;
f) ±1 % pour la capacité.

Ces tolérances comprennent l'exactitude combinée des appareils de mesure, des techniques de mesure utilisées et de toute autre source d'erreur dans la procédure d'essai.

6.1.5 Prédécharge

Lorsqu'un essai exige une prédécharge, les éléments d'essai ou les piles d'essai doivent être déchargés à leur profondeur respective de décharge, sur une charge résistive avec laquelle la capacité assignée est obtenue, ou à un courant spécifié par le fabricant.

6.1.6 Éléments supplémentaires

Si des éléments supplémentaires sont exigés pour réaliser un essai, ils doivent être du même type et, de préférence, du même lot de production que l'élément d'essai.

6.2 Évaluation des critères d'essai

6.2.1 Court-circuit

Un court-circuit est considéré s'être produit pendant un essai si la tension en circuit ouvert de l'élément ou de la pile immédiatement après l'essai est inférieure à 90 % de sa valeur avant l'essai. Cette exigence n'est pas applicable aux éléments ni aux piles d'essai complètement déchargés.

6.2.2 Échauffement excessif

Un échauffement excessif est considéré s'être produit pendant un essai si la température extérieure du boîtier de l'élément ou de la pile d'essai dépasse 170 °C.

6.2.3 Fuite

Une fuite est considérée s'être produite pendant un essai si de l'électrolyte ou une autre matière s'échappe de manière visible de l'élément ou de la pile d'essai, ou s'il y a une perte de matière (à l'exception du boîtier de pile, des dispositifs de manipulation ou des étiquettes) de l'élément ou de la pile d'essai correspondant à une perte de masse dépassant les limites consignées dans le Tableau 3.

L'équation suivante est donnée pour quantifier la perte de masse $\Delta m / m$:

$$\Delta m / m = \frac{m_1 - m_2}{m_1} \times 100\ \%$$

où

m_1 est la masse avant un essai;

m_2 est la masse après un essai.

Tableau 3 – Limites de perte de masse

Masse de l'élément ou de la pile m	Limite de perte de masse $\Delta m / m$
m < 1 g	0,5 %
1 g ≤ m ≤ 75 g	0,2 %
m > 75 g	0,1 %

6.2.4 Dégazage

Un dégazage est considéré s'être produit si, au cours d'un essai, et par suite d'une augmentation excessive de la pression interne, des gaz s'échappent d'un élément ou d'une pile par un dispositif de libération de la pression conçu à cet effet. Ces gaz peuvent contenir des matériaux piégés.

6.2.5 Feu

Un feu est considéré s'être produit si, au cours d'un essai, des flammes sont produites par l'élément ou la pile d'essai.

6.2.6 Rupture

Une rupture est considérée s'être produite si le conteneur d'un élément ou le boîtier d'une pile a subi une défaillance mécanique, entraînant une expulsion de gaz ou un déversement de liquides, mais sans éjection forcée de matériaux solides.

6.2.7 Explosion

Une explosion est considérée s'être produite si le conteneur d'un élément ou le boîtier d'une pile s'ouvre avec éjection violente de composants solides. Pendant les essais réalisés sur des éléments ou des éléments composants, l'éjection de composants internes est acceptable. L'énergie des composants éjectés doit être limitée. Si cela est exigé, la mesure peut être réalisée comme suit:

a) il n'y a pas de pénétration dans un écran grillagé (constitué de fils d'aluminium recuit d'un diamètre de 0,25 mm avec une densité de grille de 6 fils à 7 fils par centimètre) placé à 25 cm de l'élément; ou

b) la mesure peut être réalisée en suivant une méthode qui a été démontrée équivalente à celle décrite en a).

6.3 Essais et exigences – Vue d'ensemble

Le présent document fournit des essais de sécurité pour l'utilisation prévue (essais A à D) et les mauvais usages raisonnablement prévisibles (essais E à M). Le Tableau 4 contient une vue d'ensemble des essais et des exigences concernant l'utilisation prévue et les mauvais usages raisonnablement prévisibles.

Tableau 4 – Essais et exigences

Numéro d'essai		Désignation	Exigences
Essais relatifs à l'utilisation prévue	A	Altitude	NL, NV, NC, NR, NE, NF
	B	Cycles thermiques	NL, NV, NC, NR, NE, NF
	C	Vibrations	NL, NV, NC, NR, NE, NF
	D	Chocs	NL, NV, NC, NR, NE, NF
Essais relatifs à de mauvais usages raisonnablement prévisibles	E	Court-circuit extérieur	NT, NR, NE, NF
	F	Impact	NT, NE, NF
	G	Écrasement	NT, NE, NF
	H	Décharge forcée	NE, NF
	I	Charge anormale	NE, NF
	J	Chute libre	NV, NE, NF
	K	Température élevée	NE, NF
	L	Installation incorrecte	NE, NF
	M	Décharge excessive	NE, NF

Les essais A à E doivent être exécutés les uns après les autres sur le même élément ou la même pile.
Les essais F et G sont des variantes. Seul l'un d'entre eux doit être exécuté.

Légende

NC: Pas de court-circuit
NE: Pas d'explosion
NF: Pas d'incendie
NL: Pas de fuite
NR: Pas de rupture
NT: Pas d'échauffement excessif
NV: Pas de ventilation

Voir 6.2 pour une description détaillée des critères d'essai.

6.4 Essais relatifs à l'utilisation prévue

6.4.1 Essai A: Altitude

a) Objet

Cet essai simule les conditions de basse pression propres au transport aérien.

b) Procédure d'essai

Les éléments et piles d'essai doivent être stockés à une pression ne dépassant pas 11,6 kPa pendant au moins 6 h à température ambiante.

c) Exigences

Il ne doit y avoir ni fuite, ni dégazage, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.4.2 Essai B: Cycles thermiques

a) Objet

Cet essai évalue l'intégrité de l'étanchéité des éléments et des piles et celle de leurs connexions électriques internes. L'essai est exécuté en appliquant des cycles de température.

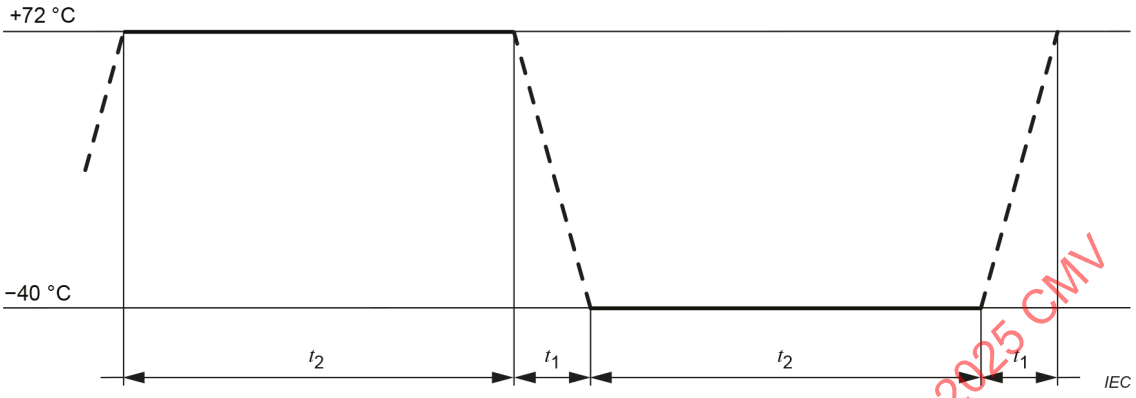
b) Procédure d'essai

Les éléments et piles d'essai doivent être stockés pendant au moins 6 h à une température d'essai de 72 °C, puis stockés pendant au moins 6 h à une température d'essai de –40 °C. La durée maximale de transition vers chaque température doit être de 30 min. Chacun des éléments et piles d'essai doit être soumis à cette procédure 10 fois. Celle-ci est suivie par un stockage pendant au moins 24 h à température ambiante.

Pour les grands éléments et les grandes piles, la durée d'exposition aux températures d'essai doit être d'au moins 12 h au lieu de 6 h.

La Figure 1 représente un schéma de l'un des dix cycles thermiques.

L'essai doit être réalisé en utilisant les éléments et les piles d'essai précédemment soumis à l'essai d'altitude.



Légende

t_1 ≤ 30 min

t_2 ≥ 6 h (12 h pour les grands éléments et les grandes piles)

Figure 1 – Procédure pour les cycles thermiques

c) Exigences

Il ne doit y avoir ni fuite, ni dégazage, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.4.3 Essai C: Vibrations

a) Objet

Cet essai simule des vibrations survenant pendant le transport. Les conditions d'essai sont fondées sur la gamme de vibrations fournie par l'OACI [2].

b) Procédure d'essai

Les éléments et piles d'essai doivent être solidement fixés à la plate-forme du générateur de vibrations, sans déformation et de manière à transmettre fidèlement les vibrations. Les éléments et piles d'essai doivent être soumis à des vibrations sinusoïdales selon le Tableau 5, qui stipule une amplitude d'accélération supérieure différente pour les grandes piles. Ce cycle doit être répété 12 fois pendant 3 h au total, pour chacune des trois positions de montage mutuellement perpendiculaires. Une des directions doit être perpendiculaire à la face des bornes.

L'essai doit être réalisé en utilisant les éléments et les piles d'essai précédemment soumis à l'essai de cycles thermiques.

Tableau 5 – Profil de vibrations (sinusoïdales)

Plage de fréquences		Amplitudes	Durée du cycle de balayage logarithmique (7 Hz – 200 Hz – 7 Hz)	Axe	Nombre de cycles
De	À				
f_1 = 7 Hz	f_2	a_1 = 1 g_n	15 min	X	12
f_2	f_3	s = 0,8 mm		Y	12
f_3	f_4 = 200 Hz	a_2		Z	12
et retour à f_1 = 7 Hz				Total	36

Légende

f_1, f_4 fréquences inférieure et supérieure

f_2, f_3 fréquences de transfert;

f_2 ≈ 17,62 Hz; et

f_3 ≈ 49,84 Hz, sauf pour les grandes piles, pour lesquelles f_3 ≈ 24,92 Hz

a_1, a_2 amplitudes d'accélération; a_2 = 8 g_n, sauf pour les grandes piles, pour lesquelles a_2 = 2 g_n

s amplitude de déplacement

NOTE 1 L'amplitude de vibration est la valeur absolue maximale de déplacement ou d'accélération. Par exemple, une amplitude de déplacement de 0,8 mm correspond à un déplacement crête à crête de 1,6 mm.

NOTE 2 g_n = 9,806 65 m / s^2

c) Exigences

Il ne doit y avoir ni fuite, ni dégazage, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.4.4 Essai D: Chocs

a) Objet

Cet essai simule des manipulations brutales survenant pendant le transport.

b) Procédure d'essai

Les éléments et piles d'essai doivent être fixés sur l'appareil d'essai au moyen d'un montage rigide venant au contact de toutes les faces de chacun des éléments ou piles d'essai. Chaque élément ou pile d'essai doit être soumis à 3 chocs selon chaque direction des trois positions de montage mutuellement perpendiculaires de l'élément ou de la pile, ce qui correspond à 18 chocs au total. Pour chaque choc, les paramètres donnés dans le Tableau 6 doivent être appliqués.

Tableau 6 – Paramètres de chocs

	Forme d'onde	Accélération de crête	Durée des impulsions	Nombre de chocs par demi-axe
Éléments ou piles, sauf ceux de grand format	Semi-sinusoïdale	150 g_n	6 ms	3
Grands éléments ou grandes piles	Semi-sinusoïdale	50 g_n	11 ms	3
NOTE g_n = 9,806 65 m / s^2				

Pour les piles électriques au lithium dont la masse dépasse 4,482 kg, la méthode de l'essai T-4 de l'IEC 62281 peut être utilisée.

L'essai doit être réalisé en utilisant les éléments et les piles d'essai précédemment soumis à l'essai de vibrations.

c) Exigences

Il ne doit y avoir ni fuite, ni dégazage, ni court-circuit, ni rupture, ni explosion, ni feu au cours de cet essai.

6.5 Essais relatifs à de mauvais usages raisonnablement prévisibles

6.5.1 Généralités

Les méthodes d'essai décrites ci-après ont été développées pour les piles spécifiées dans l'IEC 60086-2. Cependant, elles doivent également s'appliquer aux piles qui n'y sont pas spécifiées. Pour les piles non spécifiées dans l'IEC 60086-2, les exigences supplémentaires décrites dans l'Annexe G s'appliquent.

6.5.2 Essai E: Court-circuit extérieur

a) Objet

Cet essai simule les conditions entraînant un court-circuit extérieur.

b) Procédure d'essai

L'élément ou la pile d'essai doit être stabilisé à une température extérieure du boîtier de 55 °C et ensuite soumis à un état de court-circuit avec une résistance externe totale inférieure à 0,1 Ω à 55 °C. Cet état de court-circuit est maintenu pendant au moins 1 h après retour à 55 °C de la température extérieure du boîtier de l'élément ou de la pile.

Pour les piles électriques au lithium dont la masse dépasse 12 kg, la méthode de l'essai T-5 de l'IEC 62281 peut être utilisée.

L'échantillon d'essai doit être observé pendant une durée supplémentaire de 6 h.

L'essai doit être réalisé en utilisant les échantillons d'essai précédemment soumis à l'essai de chocs.

c) Exigences

Il ne doit se produire aucun échauffement excessif, aucune rupture, aucune explosion ou aucun feu pendant cet essai et pendant le temps d'observation de 6 h.

6.5.3 Essai F: Impact

a) Objet

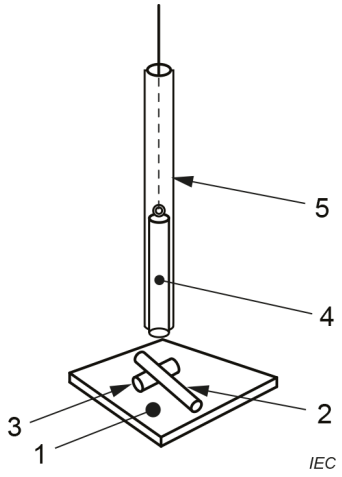
Cet essai simule les sévices mécaniques résultant d'un impact qui peut conduire à un court-circuit interne.

b) Procédure d'essai

L'essai d'impact est applicable aux éléments cylindriques d'au moins 18 mm de diamètre.

L'élément d'essai ou l'élément composant est placé sur une surface plane et lisse. Une barre d'acier inoxydable (de type 316 ou équivalent) de 15,8 mm ± 0,1 mm de diamètre et d'une longueur d'au moins 60 mm ou de la dimension la plus grande de l'élément, la plus élevée de ces deux valeurs étant retenue, est placée sur le centre de l'échantillon d'essai. Une masse de 9,1 kg ± 0,1 kg est lâchée d'une hauteur de 61 cm ± 2,5 cm à l'intersection de la barre et de l'échantillon d'essai, de façon contrôlée, au moyen d'un rail ou d'une goulotte de guidage vertical pratiquement sans frottement et présentant une résistance de traînée minimale sur la masse en chute. Le rail ou la goulotte de guidage vertical utilisé pour guider la masse en chute doit être incliné à 90 degrés par rapport à la surface horizontale supportant le dispositif.

L'échantillon d'essai doit subir l'impact en ayant son axe longitudinal parallèle à la surface plane et perpendiculaire à l'axe longitudinal de la barre en acier inoxydable reposant au centre de l'échantillon d'essai (voir la Figure 2).



NOTE La figure montre une surface plane et lisse (1) et une barre en acier inoxydable (2) qui est placée sur le centre de l'échantillon d'essai (3). Une masse (4) tombe à l'intersection, de façon contrôlée au moyen d'une goulotte de guidage vertical (5).

Figure 2 – Exemple de montage d'essai pour l'essai d'impact

Chaque élément d'essai ou élément composant doit être soumis à un seul impact.

L'échantillon d'essai doit être observé pendant une durée supplémentaire de 6 h.

L'essai doit être réalisé en utilisant des éléments d'essai ou des éléments composants qui n'ont pas été précédemment soumis à d'autres essais.

c) Exigences

Il ne doit se produire aucun échauffement excessif, aucune explosion ni aucun feu pendant cet essai et pendant le temps d'observation de 6 h.

6.5.4 Essai G: Écrasement

a) Objet

Cet essai simule les sévices mécaniques résultant d'un écrasement qui peut conduire à un court-circuit interne.

b) Procédure d'essai

L'essai d'écrasement est applicable aux éléments de type bouton, parallélépipédiques, souples, et aux éléments cylindriques de diamètre inférieur à 18 mm.

Un élément ou élément composant doit être écrasé entre deux surfaces planes. L'écrasement doit être progressif, effectué à une vitesse d'environ 1,5 cm/s au moment du premier contact. L'écrasement doit être maintenu jusqu'à ce que l'une des trois conditions ci-dessous soit obtenue:

1) la force appliquée atteint 13 kN ± 0,78 kN;

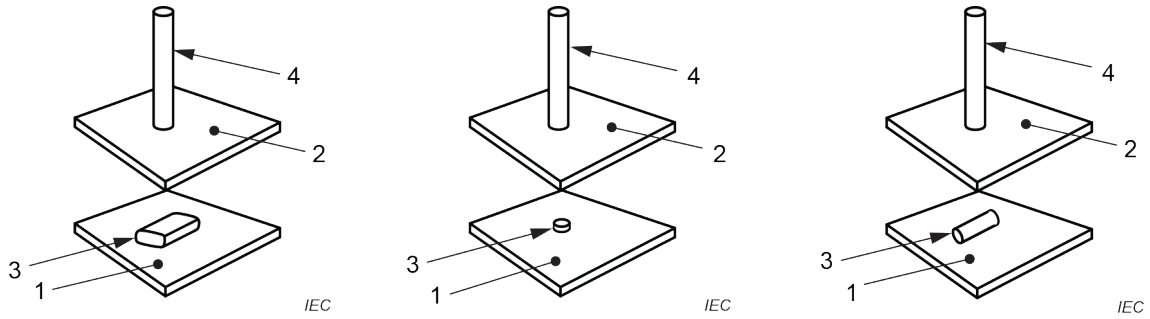
EXEMPLE: La force peut être appliquée par un vérin hydraulique avec un piston de 32 mm de diamètre jusqu'à ce qu'une pression de 17 MPa soit atteinte sur le vérin hydraulique.

2) la tension de l'élément chute d'au moins 100 mV; ou

3) l'élément est déformé d'au moins 50 % par rapport à son épaisseur d'origine.

Dès que l'une des conditions ci-dessus est remplie, la pression doit être relâchée.

Un élément parallélépipédique ou souple doit être écrasé en appliquant la force sur le côté ayant la surface la plus grande. Un élément bouton lithium doit être écrasé en appliquant la force sur ses surfaces planes. Pour les éléments cylindriques, la force d'écrasement doit être appliquée perpendiculairement à l'axe longitudinal. Voir la Figure 3.



a) Élément parallélépipédique ou souple **b) Élément bouton** **c) Élément cylindrique**

NOTE Les figures montrent deux surfaces planes (1 et 2) avec des piles (3) de formes différentes placées entre elles pour l'écrasement, au moyen d'un piston (4).

Figure 3 – Exemples de montage d'essai pour l'essai d'écrasement

Chaque élément d'essai ou élément composant doit être soumis à un seul écrasement.

L'échantillon d'essai doit être observé pendant une durée supplémentaire de 6 h.

L'essai doit être réalisé en utilisant des éléments d'essai ou des éléments composants qui n'ont pas été précédemment soumis à d'autres essais.

c) Exigences

Il ne doit se produire aucun échauffement excessif, aucune explosion ni aucun feu pendant cet essai et pendant le temps d'observation de 6 h.

6.5.5 Essai H: Décharge forcée

a) Objet

Cet essai évalue la capacité d'un élément à résister à une condition de décharge forcée.

b) Procédure d'essai

Chaque élément doit être soumis à une décharge forcée à température ambiante en le connectant en série à une alimentation en courant continu de 12 V à un courant initial égal au courant de décharge continu maximal spécifié par le fabricant.

Le courant de décharge spécifié est obtenu en connectant une charge résistive de taille et de caractéristiques assignées appropriées en série avec l'élément d'essai et l'alimentation en courant continu. Chaque élément doit être soumis à une décharge forcée pendant une durée égale à sa capacité assignée divisée par le courant d'essai initial.

Cet essai doit être réalisé en utilisant des éléments d'essai ou des éléments composants complètement déchargés, qui n'ont pas été précédemment soumis à d'autres essais.

c) Exigences

Il ne doit se produire ni explosion ni feu au cours de cet essai et dans les 7 jours qui suivent l'essai.

6.5.6 Essai I: Charge anormale

a) Objet

Cet essai simule la condition dans laquelle une pile est installée dans un dispositif et se trouve exposée à un courant inverse (charge) provenant d'une alimentation externe, par exemple une unité de sauvegarde de mémoire comportant une diode défectueuse (voir 7.1.2). La condition d'essai repose sur l'UL 1642 [19].

NOTE Cet essai ne prend pas en compte le cas où une pile est soumise à un mauvais usage correspondant à une insertion dans un chargeur de batterie (confusion involontaire avec une pile rechargeable).